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Memory Development Between 2 and 20

Springer-Verlag

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With 17 Illustrations

Springer-Verlag
New York Berlin Heidelberg
London Paris Tokyo

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Library of Congress Cataloging-in-Publication Data
Schneider, Wolfgang, 1953–
Memory development between 2 and 20.
(Springer series in cognitive development)
Bibliography: p.
Includes index.
1. Memory in children. 2. Memory in youth.
I. Pressley, Michael. II. Title. III. Title: Memory development between two and twenty. IV. Series.
BF723.M4S35 1988 155.4'13 88-15981

Printed on acid-free paper.

Typeset by Publishers Service, Bozeman, Montana
Printed and bound by Edwards Brothers, Inc., Ann Arbor, Michigan
Printed in the United States of America.

9 8 7 6 5 4 3 2 1

ISBN 0-387-96742-7 Springer-Verlag New York Berlin Heidelberg
ISBN 3-540-96742-7 Springer-Verlag Berlin Heidelberg New York

Series Preface

For some time now, the study of cognitive development has been far and away the most active discipline within developmental psychology. Although there would be much disagreement as to the exact proportion of papers published in developmental journals that could be considered cognitive, 50% seems like a conservative estimate. Hence, a series of scholarly books devoted to work in cognitive development is especially appropriate at this time

The *Springer Series in Cognitive Development* contains two basic types of books, namely, edited collections of original chapters by several authors, and original volumes written by one author or a small group of authors. The flagship for the Springer Series is a serial publication of the "advances" type, carrying the subtitle *Progress in Cognitive Development Research*. Each volume in the *Progress* sequence is strongly thematic, in that it is limited to some well-defined domain of cognitive-developmental research (e.g., logical and mathematical development, development of learning). All *Progress* volumes will be edited collections. Editors of such collections, upon consulting with the Series Editor, may elect to have their books published either as contributions to the *Progress* sequence or as separate volumes. All books written by one author or a small group of authors are being published as separate volumes within the series.

A fairly broad definition of cognitive development is being used in the selection of books for this series. The classic topics of concept development, children's thinking and reasoning, the development of learning, language development, and memory development will, of course, be included. So, however, will newer areas such as social-cognitive development, educational applications, formal modeling, and philosophical implications of cognitive-developmental theory. Although it is anticipated that most books in the series will be empirical in orientation, theoretical and philosophical works are also welcome. With books of the latter sort, heterogeneity of theoretical perspective is encouraged, and no attempt will be made to foster some specific theoretical perspective at the expense of others (e.g., Piagetian versus behavioral or behavioral versus information processing).

C.J. Brainerd

Preface

We first met in May 1982 at the University of Notre Dame. MP was a visiting professor and WS was touring the United States as part of a leave from the Max Planck Institute to Stanford. At the time of the meeting, we had both been researching memory development for some time and had been thinking about metamemory in particular. It was apparent immediately that we shared many of the same points of view. We both had a no-nonsense, "what-do-the-data-say" attitude about the study of memory development. MP was particularly impressed by WS's thorough analysis of metamemory, one eventually published as Schneider (1985c).

We met again from time to time at conferences. In the summer of 1984, MP came to the Max Planck Institute, a visit reciprocated by WS to the University of Western Ontario in the spring of 1985. At that time we were working on the good strategy user model (along with John Borkowski). The result was an integrative framework for thinking about memory functioning, one that included cognitive, metacognitive, and noncognitive components. The latest version is taken up in Chapters 6 and 7 of this volume.

The summer of 1986 brought MP back to Munich, as WS was finishing his habilitation. It was clear that we were once again thinking about many of the same issues, and once again, the differences in our thinking were much smaller than the similarities. There seemed to be good reason to think about putting our common thoughts into a book. WS suggested parts of his habilitation as a starting point; MP agreed. This volume is the result of many rewritings and reworkings from that point of departure. We especially tried to focus on the main themes and methods in memory development. We felt it important, however, to take positions on some of the more controversial issues of the day. We debated long and hard about some of the perspectives offered here, but in the end believe that our conclusions are eminently defensible in light of the available data. We also went well beyond the habilitation, especially in developing our theory of good strategy use in light of the extensive memory development data base.

This book is intended for a number of audiences. First of all, it is meant as a coherent introduction to memory development for students and professionals who have little background in either cognitive or developmental psychology. We tried to write a good book for advanced undergraduate and first- and second-year graduate courses. It is also a volume for our peers, however, in that we do try to provide clear stances on many of the major issues of the day. We worked hard to separate the "wheat from the chaff" and, thus, have identified the literature that we hope our peers will consider seriously as they plan future research. There was no hesitation to indicate gaps in the literature, thus hoping that some of the senior scientific community might be stimulated by our discussion and consider filling in those gaps. For student readers, these gaps might provide many thesis and dissertation opportunities.

This volume will be updated with a second edition in a few years. Most of the revision will follow from new work that will appear in the literature, but some of it will involve rethinking the work already conducted. Please do not hesitate to let us know if you believe that some data and/or interpretations not presented in this volume should be considered for the revision.

There are a lot of people who deserve thanks for their contributions to our work. Both of us agree that John Flavell has influenced our thinking enormously. WS has visited Stanford several times in the 1980s; John was MP's advisor during his early graduate school years. Flavell's influence is apparent throughout this volume. Our mutual friend and frequent coauthor John Borkowski also deserves thanks. He continuously challenges us to think about memory differently than we would have otherwise. Many of these ideas were developed in part in the South Dining Hall on the campus of the University of Notre Dame. WS acknowledges the support of his colleagues and staff at the Max Planck Institute. He is particularly grateful to Franz Weinert, who first stimulated his interest in memory development about a decade ago and has provided continuous support since then. WS's ideas about the memory-metamemory relationship have been expanded by his discussions with Marcus Hasselhorn, Joachim Körkel, Beth Kurtz, Beate Sodian, Gerhard Strube, Monika Knopf, and Michael Waldmann. MP bounced many of these ideas off his graduate students, including Barbara L. Snyder, Teresa Cariglia-Bull, Eileen Wood, and Patricia Devolder. Bill Rohwer of Berkeley and Joel Levin have provided continuous feedback for 15 years about MP's work on elaboration, some of which is summarized in Chapter 7.

We hope that we wrote a book that summarizes the field well in a fashion that is interesting. Let us know what you think.

Munich, FRG — Wolfgang Schneider

London, Ontario, Canada — Michael Pressley

Contents

1. A Brief History of Memory Development Research

The aim of this book is to give an integrative introduction to theory and research on memory development from early childhood to early adulthood. Research on memory development has been stimulated by a shift in both experimental and developmental psychology away from behaviorist theories toward cognitive theories, a shift that emphasizes information processing considerations. The discovery of Piaget by American developmental psychology (Bruner, 1964; Flavell, 1963) also encouraged the cognitive "Zeitgeist" in developmental psychology (Ornstein, 1978a). A "Symposium on Memory Development," which posed the question, "What actually develops?" (Flavell, 1971) was an additional stimulant.

While in 1965 the key word "memory" was not used in the index of *Child Development Abstracts and Bibliography* (as noted by Kail & Hagen, 1977a), every issue of that outlet now includes abstracts for a number of studies of memory. It would have been much easier to summarize this field even a decade ago (Wimmer, 1976) with most of the important research programs covered comprehensively in a single edited volume (Kail & Hagen, 1977a). Since then, there has been a dramatic increase in the amount of research and the approaches taken by memory development researchers. For instance, although Flavell and Wellman (1977) summarized most of the existing metamemory research in a single chapter, Forrest-Pressley, MacKinnon, and Waller (1985a, 1985b) published two entire volumes about metacognition research programs, with much of the research focussing on metamemory.

Students and scholars not specializing in memory development could easily be overwhelmed by the quantity and diversity of this literature. Thus, a main purpose in writing a book about the highlights of memory development is to make accessible the most important ideas and research in this area. In doing so, we focus on what we view as the main components of the memory system including short-term memory structures, memory strategies, metamemory, and the nonstrategic knowledge base. Separate chapters are dedicated to these main components, with interactions between components considered at appropriate places (e.g., strategy development as it relates to development of the nonstrategic knowledge base and to metamemory). The book concludes with chapters that focus on how the components function interactively and the challenge of improving memory through instructional development of components and their interactions. Before turning to recent research on memory development, however, we provide some history in this chapter.

1885–1935

Investigations of Immediate Memory

Most of the developmental memory studies at the turn of the century were concerned with the memory span, that is, with immediate memory. Given the interest of German psychologists in memory in general, it should not be surprising that much of the memory development research at that time was conducted in Germany. Ebbinghaus himself was concerned with memory-span capacity at different age levels, with particular interest in identifying the developmental memory-span curves for various types of materials (Ebbinghaus, 1885, 1887, 1902). Thus, many studies were conducted in which children were exposed to meaningless syllables, single-syllable words, or numbers with recall required immediately after one presentation. For instance, Ebbinghaus found that learners between 18 and 20 years of age were able to recall about 1½ more syllables or words than 8- to 10-year-old learners. It was also determined early that meaning played a significant role in determining the amount recalled (Netschajeff, 1902). For instance, whether nonsense words were one or two syllables in length had little impact on span. On the other hand, Binet and Henri (1894a, 1894b) found that preschoolers exhibited substantially better memory for sentences with many words (e.g., 38 words in length) than for short lists (e.g., seven items) of meaningless words. As a rule, the core verbal units that suggested meaning were remembered best.

Frequently, experimental investigations were commissioned for the purpose of answering particular practical questions, for instance, what the effects of intensive practice (five hours) was on the mental alertness of students. Often a number of different age groups were tapped in these investigations, making it possible to construct descriptive curves of memory-span development.

Other investigations were prompted by theoretical issues. In two studies in particular (Lobsien, 1902a; Netschajeff, 1900), 9- to 18-year-olds were administered a series of memory tasks, including immediate memory span for multidigit numbers and for serial word lists. The words on these lists included terms that described sensations (cool, hot), described sounds (music, bell) or referred to abstract concepts (cause, justice). In addition, memory for actual sounds and objects was tested. For all types of items, memory-span performance increased with age, with better memory for objects and labels describing sensations than for sounds and abstract concepts. Lobsien's analyses of the exact recall sequences yielded another important result—that memory of items in order develops later than simple free recall of list items. At all age levels, however, fewer items were produced in the correct serial order than were recalled overall.

Meumann (1907a) and Offner (1924) regarded both Lobsien's (1902a) and Netschajeff's (1900) investigations as particularly valuable in that they highlighted the existence of several memory functions that did not develop in parallel. Thus, the same 9-year-old children who could produce about 30% of a list of nonsense syllables were more successful when the trial consisted of numerical series of the same length (about 60% recall) or meaningful word lists (about 70%) (e.g., Jacobs, 1887; Lobsien, 1902a; Pohlmann, 1906). These findings, moreover, were consistent with earlier studies conducted by Kirkpatrick (1894) and Lobsien (1911a). In Kirkpatrick's study, schoolchildren were able to recall seven out of 10 meaningful words on average, regardless of whether the words were read or heard. In contrast, the subjects in Lobsien's experiment (aged 7 to 15 years) recalled only 2.3 out of 10 nonsense words on average.

A number of studies of immediate memory span were made using the "word-pair method" developed by Ranschburg (1901), the forerunner of the paired-associate learning technique. On each trial a series of word pairs were presented with subjects instructed to repeat each pair several times. At testing, the experimenter read the first pair member with subjects required to recall its pairmate. Nagy (1930) conducted experiments with this technique. His participants were 700 schoolchildren between the ages of 7 and 19. There were four different lists, each composed of 12 word pairs. Lists differed systematically in terms of the abstractness/concreteness dimension. Nagy found that abstract word pairs were harder to remember than concrete ones.

Investigations of Long-Term Memory and Forgetting

One of the first investigations of children's retention and forgetting of verbal materials (Vertes, 1913, 1931) used the word-pair method. Vertes was interested in the interval between learning and testing as a determinant of recall in children 6 to 18 years of age. The test for immediate retention was followed by two delayed tests at intervals of one day and one week. That more than 80% of the material was recalled on the immediate memory test suggests that the concrete words on the list were easy to memorize, particularly for the older children. After an interval of one day, the rate of forgetting was about 8% in the 6- to 13-year-old sample and no more than 3% in the 13- to 18-year-old group. After one week the results were astonishing for children older than 10 years of age. They actually remembered more than they had on the previous tests. Younger children (especially 6-year-olds) performed worse after a week than they had after 24 hours.

How do these findings compare with classic forgetting curves (e.g., Ebbinghaus, 1885)? Ebbinghaus conceived of forgetting as a quantitative fading of memory and a nonlinear function of passage of time. This relationship could be expressed as (retention/forgetting) = k/(log time)^c with k and c referring to constants. In everyday language, this function specified that the rate of forgetting is greater shortly after learning than it is later. Vertes results clearly did not conform to this principle, with Vertes offering three potential explanations. One was that the word-pair method was not the same approach that Ebbinghaus used to study retention and forgetting. The second was that there was already a substantial literature suggesting that forgetting did not occur as specified by Ebbinghaus' formula. The third explanation was that forgetting might be different for children than for adults.

Vertes third hypothesis is by far the most important one in this context. Vertes was aware of the comprehensive analyses of retention and forgetting in children and adults that had been made by Radossawljewitsch (1907). Radossawljewitsch's study was stimulated by criticisms of Ebbinghaus' experimental method. In particular, Meumann, Radossawljewitsch's advisor, doubted Ebbinghaus' findings because neither he nor his collaborators were able to replicate them, and because they did not accord with the experiences of everyday life and work.

Radossawljewitsch's subjects were 16 students between 20 and 40 years of age and 11 children (aged 7 to 13). The participants learned nonsense syllables and meaningful materials (poems) and were tested on immediate memory and relearning after lapses of 5 minutes, 20 minutes, 1 hour, 8 hours, and subsequently after 2, 6, 14, 30, and 60 days. Compared to adults, children needed a very large number of repetitions to learn a series for the first time, but the children forgot less of the material that was learned and their rate of forgetting seemed less than that of adults. These differences were most salient at long retention intervals (30 to 60 days). The rate of forgetting of meaningful material in both age groups was similar to the forgetting rate for nonsense syllables, but "savings" (i.e., reduction in time to relearn the material completely) were generally greater for meaningful material.

Although the slopes of the forgetting curves were different for children and adults, the most important finding was the forgetting curves obtained for the two groups did not correspond to the curve obtained by Ebbinghaus. Although the curves were in accord with the assumption that forgetting is a decelerating function of time, they differed from the curve obtained by Ebbinghaus in that forgetting did not take place as rapidly. In particular, the children's rate of forgetting was slower than the rate reported by Ebbinghaus. The discrepancy between the two sets of data was very great—Ebbinghaus forgot more information in one hour than adults in Radossawljewitsch's study forgot in eight hours. Finkenbinder (1913) conducted research aimed at reconciling the discrepancy between the outcomes in the experiments conducted by Ebbinghaus and Radossawljewitsch. Although there is no need to consider Finkenbinder's methods or results in detail, one of his main conclusions is important. He argued that the rapid rate of forgetting by Ebbinghaus was probably due to the relatively rapid rate of self-presentation in that study.

Studies of General Memory Development

A study by Brunswik, Goldscheider, and Pilek (1932) differed from earlier investigations in that the goal was to provide a general description of memory in school-age children. In addition, the issues addressed in this study were derived directly from a truly developmental theory, Charlotte and Karl Bühler's doctrine of phases and stages. The study was also unique compared to previous research in that statistical significance tests were used. Brunswik et al.'s (1932) experiments focused on verbal memory of children 6 to 18 years of age. For the younger students in the study, nonsense syllables, one-syllable words, and numbers were used as the learning materials and only immediate retention was tested. The tests for older students involved short-term and long-term memory for poems, memory of Bühler's paired concepts (e.g., rabbit and fir tree-Easter and Christmas), as well as "Mars number tasks," another pair-associate test involving combinations of numbers and nonsense syllables.

Six- to 13-year-olds required more practice to learn nonsense syllables than words or numbers. This difference was particularly marked for the youngest children. With increasing age, the number of repetitions to learn these types of materials declined. The findings for the older students, however, were not equally clearcut. While the typical age trend was obtained with the Mars numbers (i.e., olders learned more easily), no age differences were reported for the two tasks involving more meaningful materials (poems and paired concepts). For the paired-concepts task, this was probably due to marked ceiling effects. That was not the case for poems, however.

Although no exact figures were reported for delayed recall, the results with meaningful learning materials were generally similar to the findings reported by Vertes (1913, 1931)—higher scores were obtained after one week than had been obtained at immediate recall. As in Vertes' work, the rate of forgetting was greater for the older subjects compared to the younger ones.

In addition to the tests of verbal memory, Brunswik et al. (1932) included nonverbal tests of memory span. The "School of Balls" test involved nine exercises with a ball, with subjects required to repeat these in correct sequence. Recall and recognition of nine geometric figures as well as serial recall of nine different colored patterns was also required. Meaningful memory span was assessed by recalling a picture story (Christmas eve), learning 24 pairs of real objects, and remembering instructions in correct sequential order (i.e., following instructions to tidy up the classroom).

The major findings on the span tasks were that memory for meaningless materials peaked by about age 12, whereas the maximum span for Gestalt memory configurations and meaningful elements continued to develop into adolescence. Given the different developmental patterns, Brunswik et al. (1932) concluded that there must be different memory functions. Their view was that the rote-associative memory system was dominant early in development and was eventually replaced by higher functions, a view that was generally consistent with the Bühlers' theories of development.

In their efforts to make their findings congruent with the Bühlers' perspectives, Brunwik et al. (1932) interpreted their complex data too uniformly, however. The alert reader will have noticed already that the conclusion that rote-associative processes predominate in young children is inconsistent with the data on the verbal learning tasks; the younger children required more practice to learn nonsense syllables than meaningful words, with continuous improvement in the learn of nonsense syllables up until age 18, even though ceiling effects were obtained with meaningful material much earlier in development. In addition, other scientists have failed to find support for the position that children can skillfully learn nonmeaningful material by rote before they can master more meaningful materials (e.g., Fechner, 1965; Weinert, 1962). For instance, Weinert found that 6-year-olds learned word pairs composed of familiar words much more easily than they learned pairs consisting of meaningless, unfamiliar syllables.

Notwithstanding its shortcomings, the study by Brunswik et al. (1932) is a valuable contribution to memory development. The use of more precise methods and various learning materials gave rise to more specific hypotheses concerning age differences in memory development. The disparate growth curves obtained for different memory functions were consistent with the data in previous studies (e.g., Netschajeff, 1900, 1902; Offner, 1924). The graphical representation of the general development of immediate memory is particularly interesting in light of the assumptions of the day about the course of memory development. Their curve was based on scores from about 700 students and represented an aggregation across all measures included in the study, using a special standardization procedure (see Fig. 1.1). The outcomes recorded in Fig. 1.1 correspond closely to those reported by Nagy (1930) and Vertes (1913, 1931) who found linear and steep rises in performance from 6 to 11 years of age. Brunswik et al.'s results are also consistent with other reports that there is a plateau in performance during pre- and early adolescence (e.g., Bourdon, 1894; Lobsien, 1911a, 1911b; Nagy, 1930; Pohlmann, 1906). On the other hand, the findings of Brunswik et al. differ substantially from the results obtained by Ebbinghaus who concluded that the period from ages 13 to 15 was characterized by a major increase in memory performance. From the slope of Brunswik et al.'s curve, it seems likely that maximum performance had not yet been obtained by age 18. This aspect of the data was consistent with Meumann's (1907a) and Pohlmann's (1906) results, indicating that immediate retention for verbal materials continues to increase up to the age of 25, and only then is there an enduring plateau in performance. Finally, the findings of Brunswik et al. (1932) concerning long-term memory for meaningless material are also supportive of Meumann's and Radossawljewitsch's earlier results. The retention of older children and adolescents appears even lower than that of younger children. The results of Brunswik et al. were also consistent with the apparently paradoxic outcomes in Vertes, indicating improvements in performance after long time intervals.

Individual Differences in Memory Development

The majority of the early studies attached great importance to the identification of interindividual differences in memory development. At the time these studies were conducted, demonstrations that adults produced superior recall than children were by no means trivial, for there were hypotheses that children would learn some types of material (e.g., nonsense syllables; Meumann, 1907a) better than adults would. In

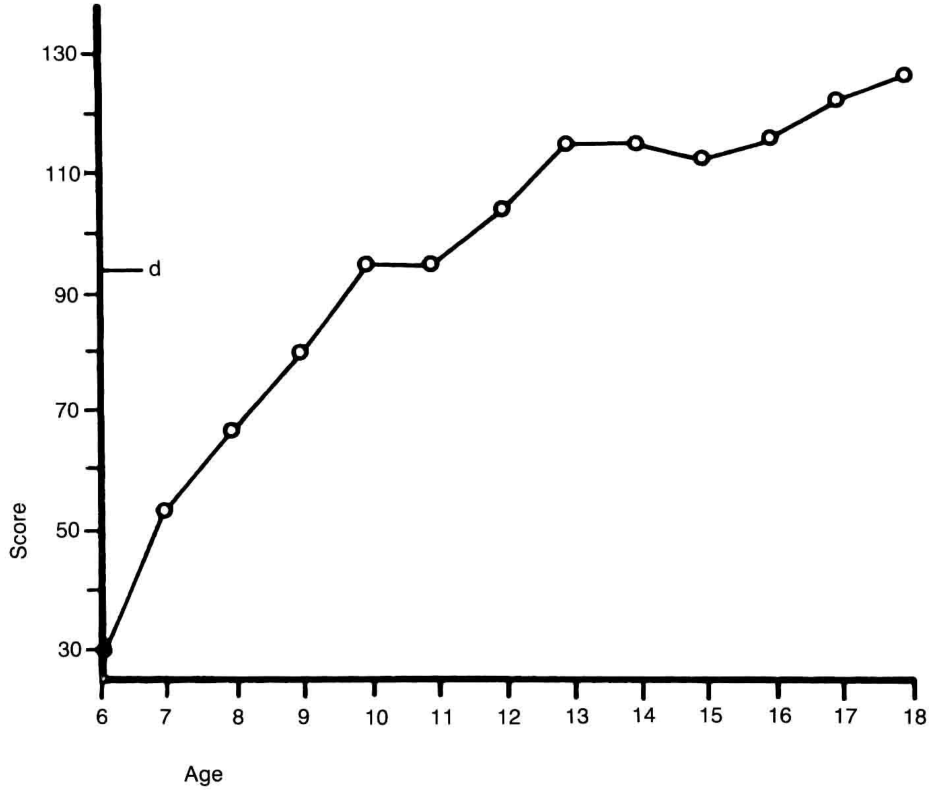

FIGURE 1.1. Memory development in children and adolescents. Data from Brunswik et al. (1932).

addition, there was a great deal of concern with sex differences. Many of the opponents of coeducation sought to win the cause of separate education by arguing that girls had inferior intellectual aptitudes. Since women were portrayed as not being able to keep up with men, coeducation was considered a "sin against nature" by some (Braunshausen, 1914, p. 95f). The early studies also dealt extensively with the possibilities that there were memory types and that there are important relationships between memory and intelligence.

SEX DIFFERENCES

Although Bolton (1892) assumed that girls were in general superior to boys, Ebbinghaus (1897), Lobsien (1911a), and Nagy (1930) all reported higher performance levels for boys in younger populations (9 to 12 years of age), while girls did better in older age groups. In general, Bolton's findings were consistent with the bulk of the data, however (e.g., Brunswik et al., 1932; Kesselring, 1911; Netschjeff, 1900; Pohlmann, 1906; Vertes, 1913, 1931), although in most cases the differences in favor of girls were small. One of the greatest difficulties in interpreting this entire literature is that any minor difference was interpreted as important, however. The study by Brunswik et al. (1932) was an exception in this respect since it included significance tests to evaluate mean differences. A comparison of sex differences across several memory tasks revealed that the differences were relatively weak, especially compared to the age differences found for the same tasks.

Memory Types

Research on memory types in children was inspired on the one hand by the everyday observation that memory for figures, melodies, stories, and other materials can vary enormously within the same person, and on the other hand by mnemonists whose proficiency seem clearly confined to one modality (Braunshausen, 1914; Offner, 1924). Classifying students into groups of acoustic-auditory, optic-visual, tactile-motor, or mixed-memory types seemed directly relevant to the design of instruction in school. There was also an interest in determining whether there is an optimal combination of visual and auditory instruction (Kemsies, 1900, 1901; Kirkpatrick, 1894).

A particularly prominent study at the turn of the century was by Netschajeff (1900) who asked students about their learning habits and classified them as visual, auditory, or motor-memory types on the basis of their responses during these interviews. It should be noted that Netschajeff was fully aware of the methodological problems arising in any such classification. For example, it was difficult to find clearcut memory types, with only about 10% of the sample classified unequivocally. In addition, the individual differences that were detected proved not to be stable (Meumann, 1907a; Pohlmann, 1906; Radossawljewitsch, 1907). Despite the difficulties, Braunshausen (1914) and Offner (1924) still regarded knowledge about memory types as potentially important in terms of practical consequences for instruction. However, use of memory types in planning instruction was never implemented extensively, although there are even contemporary attempts to show instruction to accommodate memory types (see Cronbach & Snow, 1977).

Relationships Between Intelligence and Memory

An informal observation of the day was that bright students did not always have good memories. This issue was investigated empirically by cross-classifying subjects in terms of relative academic achievement and relative memory performance. In a study of memory span, Bolton (1892) and Ebbinghaus (1897) found evidence in support of the everyday observation. The correlations between academic achievement and memory span were low. Others, however, found more striking relationships between simple memory performance and achievement (e.g., Binet, 1909; Bourdon, 1894; Meumann, 1912; Pohlmann, 1906; Winch, 1906). Meumann's and Binet's studies were particularly noteworthy in that academic ability was not inferred from school achievement, but was instead measured using psychometric and experimental techniques. Not surprisingly, the more meaningful and complex the to-be-memorized materials, the greater the correlation between memory and intelligence (Brunswik et al., 1932; Vertes, 1913, 1931). When all of the data were considered, the relationship between intelligence and memory performance proved positive, although the correlations were not particularly high in many cases. This finding seems to be in line with Bolton's (1892) conclusion:

> Intellectual acuteness, while more often accompanied by a good memory span and great power of concentrated and prolonged attention, is not necessarily accompanied by them (p. 379).

SUMMARY

In the first three decades following Ebbinghaus' classic work, a great number of studies of children's memory were undertaken using methods closely related to the paradigms of general memory research. Much of this research was conducted in Germany. The large number of replication studies make clear that early research on memory development was systematic and programmatic. Interest focused more on performance than on process. The major conclusions that could be drawn from the data available by the mid-1930s can be summarized briefly:

1. In general, memory performance (e.g., immediate recall) improves over the school years and continues increasing until about the age of 25.
2. A particularly steep, linear increase in levels of performance can be observed between the ages of 7 and 11, with a plateau between the ages of 13 to 16.
3. The slope of the age curve differs depending on the type of memory function investigated and the type of learning material used.
4. A sharp distinction must be made between the development of immediate and long-term retention. Contrary to the findings for immediate recall, long-term retention seemed better for younger children and declined with increasing age.
5. Regardless of the age group or task studied, sex differences were small.
6. On average, there were positive correlations between memory performance and intellectual aptitude.

When these early studies are examined today, a number of deficiencies in them are apparent. For one, very few tasks were studied, and thus, it should not be surprising that the shape of the learning curve cited in summary point 3 would not prove to be general across the many memory tasks considered by contemporary workers. There were few control groups and frequent confoundings in these studies. For instance, these early investigators did not recognize the many problems associated with evaluating retention when the amount of time required to learn material varies dramatically between groups, as it did between children and adults (e.g., Underwood, 1964). Contemporary recognition of this methodological difficulty makes obvious one factor that may have accounted for children's retention seeming to be better than adults' retention in these early studies. Finally, there were few inferential statistical analyses in these studies. Despite these reservations, we emphasize how impressive it is that generally replicable findings emerged from this work. These pioneers made a lot of important progress.