



Psychology Press

SECOND EDITION

A long, wooden pier extends from the foreground into the distance over a body of water. The pier is supported by numerous wooden posts and has a railing made of thick ropes. The water is a clear, light blue-green color, and the sky is a clear, bright blue. The perspective is from a low angle, looking down the length of the pier.

MEMORY

Alan Baddeley • Michael W. Eysenck • Michael C. Anderson

MEMORY

This best-selling textbook presents a comprehensive and accessible overview of the study of memory. Written by three of the world's leading researchers in the field, it contains everything the student needs to know about the scientific approach to memory and its applications.

Each chapter of the book is written by one of the three authors, an approach which takes full advantage of their individual expertise and style, creating a more personal and accessible text. This enhances students' enjoyment of the book, allowing them to share the authors' own fascination with human memory. The book also draws on a wealth of real-world examples throughout, showing students exactly how they can relate science to their everyday experiences of memory.

Key features of this edition:

- thoroughly revised throughout to include the latest research and updated coverage of key ideas and models;
- a brand new chapter on “Memory and the Brain,” designed to give students a solid understanding of methods being used to study the relationship between memory and the brain, as well as the neurobiological basis of memory;
- additional pedagogical features to help students engage with the material, including many “try this” demonstrations, points for discussion, and bullet-pointed chapter summaries.

The book is supported by a Companion Website featuring extensive online resources for students and lecturers.

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“For Hilary” — Alan Baddeley

“To Christine with love” — Michael W. Eysenck

*“In memory of my father, Albin F. Anderson, a model of creativity
and vision” — Michael C. Anderson*

MEMORY

SECOND EDITION

ALAN BADDELEY,

MICHAEL W. EYSENCK,

AND MICHAEL C. ANDERSON

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ABOUT THE AUTHORS



Having graduated in Psychology from University College London, Alan Baddeley spent the following year at Princeton, the first of five such stays in the US. He returned to a post at the Medical Research Council Applied Psychology Unit (APU) in Cambridge, completing a Ph.D. concerned with the design of postal codes. He continued to combine applied research, for example on deep-sea diving, with theoretical issues such as the distinction between long- and short-term memory. After moving to the University of Sussex, he and Graham Hitch proposed a multicomponent model of working memory. He also began working with amnesic patients, continuing both these lines of research when he moved, first to a chair at the University of

Stirling, then returning to the APU in Cambridge. After 20 years as its Director, he moved first to the University of Bristol, then to his current position in York where he has resumed his collaboration with Graham Hitch. He was awarded a CBE for his contributions to the study of memory, is a Fellow of the Royal Society, of the British Academy and of the Academy of Medical Sciences.

Michael W. Eysenck graduated from University College London. He then moved immediately to Birkbeck University of London as a lecturer, where he completed his Ph.D. on the von Restorff and “release” memory effects. His research for several years focused on various topics within memory research (e.g. levels of processing; distinctiveness). However, for many years his research has focused mainly on anxiety and cognition (including memory). Most of this research has involved healthy populations but some has dealt with cognitive biases (including



memory ones) in anxious patients. This research has been carried out at Birkbeck University of London and at Royal Holloway University of London, where he has been Professor of Psychology since 1987 (Head of Department, 1987–2005). However, it was started during his time as Visiting Professor at the University of South Florida. He has published 40 books in psychology (many relating to human memory), including two research monographs on anxiety and cognition. He has been in 'Who's Who' since 1989.



Michael C. Anderson received his Ph.D. in Cognitive Psychology from the University of California, Los Angeles in 1994. After completing a post-doctoral fellowship in cognitive neuroscience at the University of California, Berkeley, he joined the psychology faculty at the University of Oregon, where he was director of the Memory Control Laboratory through 2007. Anderson is now Senior Scientist and Programme Leader at the MRC Cognition and Brain Sciences Unit in Cambridge England. His research investigates the roles of inhibitory processes as a cause of forgetting in long-term memory. Anderson's recent work has focused on executive control as a model of motivated forgetting, and has established the existence of cognitive and neurobiological mechanisms by

which we can willfully forget past experiences. This work begins to specify the mechanisms by which people adapt the functioning of their memories in the aftermath of traumatic experience.

PREFACE TO THE FIRST EDITION

Some years ago, one of us (ADB) accepted an invitation to write a memory book for the general public. The result, *Your Memory: A User's Guide*, took the basic structure of an introductory memory course, but illustrated its points from personal observation and research on everyday memory. Although not designed as a text book, it began to be used, in both its initial and in a somewhat modified form, for introductory memory courses, proving popular with students who liked its more relaxed approach. There have, however, been substantial developments in the study of memory since it was first written. This has included a much more extensive body of research on everyday memory, leading to the suggestion of producing a new book that attempts to keep the virtues of the original, while presenting an updated and extended account of human memory, explicitly designed as a memory text. The three of us jointly agreed to take on this task. In order to keep the personal tone, we agreed that each of us would undertake a number of chapters according with our interests, rather than attempt a more corporate style. Each chapter is therefore identified with one of the three authors.

One issue in writing a memory book is the question of how it should be structured. After a good deal of thought we have opted for the standard approach of following information through the memory system, beginning with sensory memory going on to discuss short-term and working memory, followed

by episodic memory which in turn leads to semantic memory and the accumulation of knowledge. There is, of course, substantial work that depends upon this basic framework but goes beyond it, with topics such as autobiographical memory, prospective memory, memory development and aging, amnesia; and applied issues such as eyewitness testimony and improving your memory. We have chosen to treat such topics separately, while at the same time referring back to earlier chapters. This means that a given topic may be described more than once, often by more than one author. We regard this as a form of distributed practice and hence an advantage rather than a drawback.

A more serious problem is presented by the limitations of the simple information flow structure. First of all, it has become increasingly clear that information flows in both directions, with memory reflecting an alliance of *interactive* systems. For example, working memory plays an important role in long-term learning, but is itself influenced by existing knowledge. We try to make this clear without unduly complicating the picture.

A second problem concerns the different levels of development of research and theory in different areas. In tackling a given area, we tend to approach it from a historical viewpoint, both because of the importance of the early work for subsequent development, and also because earlier work is usually conceptually simpler, providing a clear route into subsequent more complex theory. However, while this might work

well *within* chapters, it does not always work for the between-chapter structure. The chapters on short-term and working memory for instance, describe an area that has developed hugely since the 1960s, in the depth and complexity of theoretical development, in the degree of involvement of neuropsychology and neuroimaging, and in breadth of application. Other areas of equal importance are easier to understand. The role of organization in long-term learning for instance is a topic where the basic phenomena and ground rules had been established by the 1970s, with little further development necessary. Many newer applications such as the study of autobiographical memory and prospective memory are still at a relatively early stage of theoretical development, and as a result probably present less of a challenge to the student than some of the earlier chapters. We have therefore tried to structure the book in such a way as to allow the user to pick a different route through the book, if preferred.

In the twenty-first century, no memory book can be complete without taking into account the implications of recent exciting developments in neuroscience. Two of us (MCA and ADB) are currently involved in neuroimaging studies, and two of us (MWE and ADB) in studies involving patients with neuropsychological or emotional difficulties. However, while taking such advances into account where appropriate, our focus is on the *psychology* of human memory, which we believe will provide a sound foundation for developments in the neuroscience of memory, as well as continuing to offer a solid basis for applying knowledge gained in the laboratory to the many problems of memory in everyday life.

This project has depended crucially on the patience, help and support of our colleagues at Psychology Press including Lucy Kennedy who played an important role in planning the book, and Rebekah Edmondson, Veronica Lyons, and Tara Stebnicky who ensured that the plans became a reality. We are also grateful to Michael Forster who proposed the book and provided sustained enthusiasm for it through its long gestation. ADB's contribution owes a great deal to Lindsey Bowes, who not only typed his rambling dictations, but also provided invaluable help with finding references and overcoming the many IT glitches experienced by those of us whose semantic memory comes principally from a pre-computer age. Finally, I am grateful to my wife Hilary, for her support and tolerance of my excuses for not doing the manly chores expected of a husband, initially because I was writing a book on working memory, duly followed by my embarking on the present book. Ah well, back to the chores!

MCA is very grateful to Justin Hulbert, who made useful comments on his chapters; preparing all figures and their captions, key terms, supplementary PowerPoints, and biographies with dizzying efficiency.

MWE is also extremely grateful to his wife, Christine, for her unflagging support. She has become used to the fact that I have been involved almost continuously in book writing for the past 25 years or so. I don't have anyone to thank for typing up my chapters because (ill-advisedly or not) I have always done my own word processing!

Alan Baddeley

PREFACE TO THE SECOND EDITION

We were happy with the reception of the first edition of *Memory*, and given that the basic foundations of our understanding of memory have not changed dramatically in the last five years, have retained most of the original structure and content. The major change has been in the growing impact of neuroscience on the study of memory, something that is reflected throughout the book. Given its importance, we have added a further chapter describing the range of methods used to study memory and the brain with the aim that this will both provide an introductory overview, and a point of reference for the repeated use of such methods in studies throughout the rest of the book. In terms of general content, the degree of change varies across chapters depending on our view of the extent to which interesting and important new developments have taken place. In my own case for example, while the short-term and working memory chapters reflect several new developments, resulting in a degree of restructuring, others such as the introductory chapter and the chapter on organization and memory have fewer changes. There is also some reordering of the later chapters to form what we think is a more logical structure, together with a substantial rewrite of the chapter on amnesia using a more patient-centered approach, and discussing what happens “when memory systems fail.”

Michael Forster, the publisher whose enthusiasm led to the first edition, tells me that second editions of textbooks are usually the

best. While we would not like to discount the possibility of even better editions in the future we ourselves trust, following the helpful comments of our reviewers, that our efforts have been worthwhile.

Once again we are grateful for the efficiency and good humour of the staff at Psychology Press, and in particular to Mandy Collison and Ceri Griffiths, and to Richard Cook at Book Now who oversaw the production stage to a very tight schedule. My own contribution has again depended crucially on the skills of Lindsey Bowes in coping with my rambling dictation, helping locate references and coping with the many IT glitches that seem to conspire against me. Finally, I am again very grateful to my wife Hilary for her support and encouragement during what has proved to be a surprisingly extensive revision. I shall now have to find another reason avoiding domestic chores!

I (Michael Eysenck) would like to echo my two co-authors by expressing my heartfelt thanks to the staff at Psychology Press for their cheerful and efficient approach to the production of this book. I agree that special thanks are due to Mandy Collison, Ceri Griffiths, and Richard Book for their outstanding efforts. I am indebted to my wife Christine in every way for her continued support for my time-consuming book-writing efforts. When I have finished the book on which I am currently working for Psychology Press, I look forward to having more time available to spend with our delightful grandchildren Sebastian and Clementine.

MCA would like to express his gratitude to his partner, Nami, for her support and patience in the process of preparing this revised edition. She is very pleased that the new edition is now complete, and especially that nowhere in the text are there any stories

of embarrassing memory failures involving her (but plenty involving me, about which she feels knowingly bemused).

Alan Baddeley
York, 2014

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CHAPTER

I

WHAT IS MEMORY?

Alan Baddeley

Memory is something we complain about. Why? Why are we quite happy to claim “I have a terrible memory!” but not to assert that “I am amazingly stupid”? Of course, we do forget; we do sometimes forget appointments and fail to recognize people we have met in the past, and rather more frequently we forget their names. We do not, however, often forget important events; if the bridegroom failed to turn up for his wedding he would not be believed if he claimed to have forgotten. Consequently, failing to recognize an old acquaintance suggests that the person was perhaps not of great importance to us. The obvious excuse is to blame one’s terrible memory.

In the chapters that follow, we will try to convince you that your memory is in fact remarkably good, although fallible. We agree with Schacter (2001) who, having described what he refers to as the seven sins of memory, accepts that the sins are in fact the necessary consequences of the virtues that make our memories so rich and flexible. Our memories might be less reliable than those of the average computer but they are just as capacious, much more flexible, and a good deal more user friendly. Let us begin by considering the case of Clive Wearing who has the misfortune to have had much of his memory capacity destroyed by disease (Wilson, Baddeley, & Kapur, 1995).

WHY DO WE NEED MEMORY?

Clive is an extremely talented musician, an expert on early music who was master of a major London choir. He himself sang and was asked to perform before the Pope during a papal visit to London. In 1985, he had the misfortune to suffer a brain infection from the herpes simplex virus, a virus that exists in a large proportion of the population, typically leading to nothing worse than cold sores but very occasionally breaking through the blood-brain barrier to cause encephalitis, an inflammation of the brain that can prove fatal. In recent years, treatment has improved, with the result that patients are more likely to survive, although often having suffered from extensive brain damage, typically in areas responsible for memory.

When he eventually recovered consciousness, Clive was densely amnesic and appeared to be unable to store information for periods longer than seconds. His interpretation of his plight was to assume that he had just recovered consciousness, something that he would announce to any visitor, and something that he repeatedly recorded in a notebook, each time crossing out the previous line and writing “I have now recovered consciousness” or “consciousness has now finally been recovered,” an activity that continued for many, many years.

Clive knew who he was and could talk about the broad outlines of his early life, although the detail was very sparse. He knew he had spent 4 years at Cambridge University, but could not recognize a photograph of his college. He could remember, although somewhat vaguely, important events in his life such as directing and conducting the first modern performance of Handel's *Messiah* using original instruments in an appropriate period setting, and could talk intelligently about the historical development of the role of the musical conductor. However, even this selected knowledge was sketchy; he had written a book on the early composer Lassus, but could not recall any of the content. Asked who had written *Romeo and Juliet*, Clive did not know. He had remarried, but could not remember this. However, he did greet his new wife with enormous enthusiasm every time she appeared, even though she might only have been out of the room for a few minutes; every time he declared that he had just recovered consciousness.

Clive was totally incapacitated by his amnesia. He could not read a book or follow a television program because he immediately forgot what had gone before. If he left his hospital room, he was immediately lost. He was locked into a permanent present, something he described as "hell on earth." "It's like being dead—all the bloody time!"

However, there was one aspect of Clive's memory that appeared to be unimpaired, that part concerned with music. When his choir visited him, he found that he could conduct them just as before. He was able to read the score of a song and accompany himself on the keyboard while singing it. For a brief moment he appeared to return to his old self, only to feel wretched when he stopped playing. Over 20 years later, Clive is still just as densely amnesic but now appears to have come to terms with his terrible affliction and is calmer and less distressed.

ONE MEMORY OR MANY?

Although Clive's case makes the point that memory is crucial for daily life, it does not tell us much about the nature of memory. Clive was unfortunate in having damage to a range

of brain areas, with the result that he has problems that extend beyond his amnesia. Furthermore, the fact that Clive's musical memory and skills are unimpaired suggests that memory is not a single simple system. Other studies have shown that densely amnesic patients can repeat back a telephone number, suggesting preserved immediate memory, and that they can learn motor skills at a normal rate. As we will see later, amnesic patients are capable of a number of types of learning, demonstrating this by improved performance, even though they do not remember the learning experience and typically deny having encountered the situation before. The evidence suggests, therefore, that rather than having a single global memory system, the picture is more complex. The first few chapters of this book will try to unpack some of this complexity, providing a basis for later chapters that are concerned with the way in which these systems influence our lives, how memory changes as we move through childhood to adulthood and old age, and what happens when our memory systems break down.

In giving our account of memory, we are of course presenting a range of psychological theories. Theories develop and change, and different people will hold different theories to explain the same data. As a glance at any current memory journal will indicate, this is certainly the case for the study of memory. Fortunately, there is a great deal of general agreement between different groups studying the psychology of memory, even though they tend to use somewhat different terminology. At this point, it might be useful to say a little bit about the concept of theory that underpins our own approach.

THEORIES, MAPS, AND MODELS

What should a psychological theory look like? In the 1950s, many people thought they should look like theories from physics. Clark Hull studied the learning behavior of white rats and attempted to use his results to build a rather grand general theory of learning in which the

learning behavior of both rats and people was predicted using a series of postulates and equations that were explicitly modeled on the example set by Isaac Newton (Hull, 1943).

By contrast, Hull's great rival, Edward Tolman (1948), thought of rats as forming "cognitive maps," internal representations of their environment that were acquired as a result of active exploration. The controversy rumbled on from the 1930s to the 1950s, and then was abandoned quite suddenly. Both sides found that they had to assume some kind of representation that went beyond the simple association between stimuli impinging on the rat and its learned behavior, but neither seemed to have a solution to the problem of how these could be investigated.

The broad view of theory that we shall take is that theories are essentially like maps. They summarize our knowledge in a simple and structured way that helps us to understand what is known. A good theory will help us to ask new questions and that in turn will help us find out more about the topic we are mapping. The nature of the theory will depend on the questions we want to answer, just as in the case of maps of a city. The map that will help you travel by underground around London or New York looks very different from the sort of map that you would need if you wanted to walk, with neither being a direct representation of what you would see if you stood at a given location. That does not of course mean that they are bad maps, quite the opposite, because each map is designed to serve a different purpose.

In the case of psychological theories, different theories will operate at different levels of explanation and focus on different issues. An argument between a shopkeeper and customer, for example, would be explained in very different ways by a sociologist, who might emphasize the economic and social pressures, a social psychologist interested in interpersonal relationships, a cognitive psychologist interested in language and a physiological psychologist who might be interested in the emotional responses of the two disputants and how these are reflected in the brain. All of these explanations are relevant and in principle should be relatable to each other, but none is the single "correct" interpretation.

This is a view that contrasts with what is sometimes called **reductionism**. This assumes that the aim of science is to reduce each explanation to the level below: Social psychology to cognitive psychology, which in turn should be explained physiologically, with the physiology then being interpreted biochemically and ultimately in terms of physics. Although it is clearly valuable to be able to explain phenomena at different but related levels, this is ultimately no more sensible than for a physicist to demand that we should attempt to design bridges on the basis of subatomic particle physics, rather than Newtonian mechanics.

The aim of the present book is to outline what we know of the *psychology* of memory. We believe that an account at the psychological level will prove valuable in throwing light on accounts of human behavior at the interpersonal and social level, and will play an important role in our capacity to understand the neurobiological factors that underpin the various types of memory. We suggest that the psychology of memory is sufficiently understood to begin to interface very fruitfully with questions at both of these levels, and hope to illustrate this over the subsequent chapters.

HOW CAN WE STUDY MEMORY?

The case of Clive Wearing demonstrates how important memory is, and how complex, but leaves open the question of how it can best be studied. The attempt to understand human memory extends at least as far back as Aristotle, and forms one of the classic questions within the philosophy of mind, although without reaching any firm conclusions. This was vividly illustrated by a lecture on memory by the eminent philosopher

KEY TERM

Reductionism: The view that all scientific explanations should aim to be based on a lower level of analysis: psychology in terms of physiology, physiology in terms of chemistry, and chemistry in terms of physics.

A. J. Ayer that I attended as a student. He began, rather unpromisingly, by declaring that memory was not a very interesting philosophical question. He seems to have demonstrated this pretty effectively as I can remember none of the lecture, apart from his statement that his memory was totally devoid of imagery, prompting a skeptical questioner to ask “If I tell you that the band of the grenadier guards is marching past the end of the street, banners flying and trumpets sounding, do you not hear or see anything?” “No” replied the philosopher; “I don’t believe you!” said the questioner and sat down crossly.

This point illustrates a limitation of a purely philosophical approach to the understanding of memory in particular, and to mind in general, namely its reliance on introspection, the capacity to reflect and report our on-going thoughts. These are not unimportant, but are not a reliable indication of the way our minds work for two principal reasons. The first of these, as our example shows, is that, people differ in what they appear to experience in a given situation; does memory depend on visual imagery, and if not, why do some of us experience it? Second, and even more importantly, we are only consciously aware of a relatively small proportion of the mechanisms underpinning our mental life, and as we will see, the tip of the mental iceberg that is available to conscious awareness is not necessarily a good guide to what lies beneath.

While there are still important issues addressed by the philosophy of mind, it is now generally acknowledged these can best be pursued in collaboration with a scientific approach based on empirical evidence. To return to the question of imagery, as I suspect Ayer knew, in the late nineteenth century, Sir Francis Galton had asked a number of “eminent men” to reflect on their breakfast table from that morning and describe the vividness of the resulting memory, finding a huge range of responses. What was not known by Galton is that these huge differences are not reflected in how accurate our memories are, suggesting that accuracy depends on some nonconscious process. Could it be that different people have the same experience but just describe it differently? Or do they have different memory systems? Or perhaps they have the same basic system but have a different strategy for using it? Hence, although they are interesting, subjective

reports do not provide a very solid basis for understanding how our memory works.

So how can we move beyond introspection?

An answer to this started to develop in Germany in the latter half of the nineteenth century. It was concerned initially with the discipline of *psychophysics*, an attempt to systematically map the relationship between physical stimuli such as brightness and loudness onto their perceived magnitude. Despite success in linking physical stimuli to the psychological experience of participants, capacities such as learning and memory were initially regarded as unsuitable for experimental study. This view was dramatically overturned by a German philosopher, Herman Ebbinghaus, who conducted an intensive series of experiments on himself over a 2-year period, showing that it was indeed possible to plot systematic relationships between the conditions of learning and the amount learned. Having published this, the first classic book on the science of memory (Ebbinghaus, 1885), he moved on to



Ebbinghaus (1850–1909) was the first person to demonstrate that it was possible to study memory experimentally.

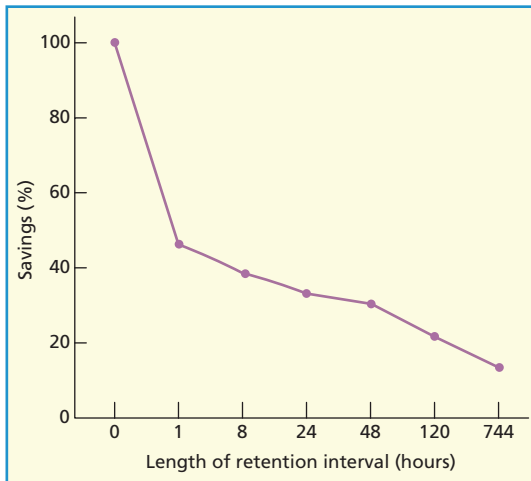


Figure 1.1 Forgetting over time as indexed by reduced savings during relearning. Data from Ebbinghaus (1885/1913).

study color vision, intelligence and a range of other questions in the newly developing field of experimental psychology.

So what did Ebbinghaus do? He began by simplifying the experimental situation, attempting to develop material that was devoid of meaning but was verbally learnable and reportable, inventing what has become known as the nonsense syllable, consonant–vowel–consonant items such as *zug*, *pj*, and *tev*. He served as his own subject, always holding constant the room in which he learned, the time of day and the rate of presentation, which was rapid, so as to avoid any temptation to attempt to find meaning in the stimuli. Ebbinghaus established some of the basic principles of learning that will be discussed in Chapter 5 and the classic forgetting curve shown in Figure 1.1 that forms the basis of all subsequent work in this area (see Chapter 9).

The Ebbinghaus tradition was subsequently most strongly developed in the US, focusing particularly on the factors and conditions surrounding the important question of how new learning interacted with what was already known. Results were interpreted in terms of associations that were assumed to be formed between stimuli and responses, using a limited range of methods that typically involved remembering lists of nonsense

syllables or words (McGeoch & Irion, 1952). This is often referred to as the **verbal learning** approach. It developed from the 1930s to the 1960s, particularly in mid-Western laboratories, and emphasized the careful mapping of phenomena rather than the ambitious building of grand theories such as that proposed by Clark Hull. When the grand theories appeared to collapse, however, the more staid approach that had previously been disparagingly discounted by its critics as “dust bowl empiricism” began to attract a broader range of investigators interested in studying learning and memory. This led to the founding of a new journal *The Journal of Verbal Learning and Verbal Behavior*, which, when the term “verbal learning” later became unfashionable, became *The Journal of Memory and Language*.

A second development that occurred at this point had its roots in both Europe and North America. In the 1930s, a German approach known as **Gestalt psychology** began attempting to apply ideas developed in the study of perception to the understanding of human memory. Unlike the behaviorist approaches, *Gestalt* psychologists tended to emphasize the importance of internal representations rather than observable stimuli and responses, and to stress the active role of the rememberer. Gestalt psychology suffered badly from Nazi persecution, but enough Gestalt psychologists moved to North America to sow the seeds of an alternative approach to verbal learning; an approach that placed much more emphasis on the activity of the learner in organizing material. This approach was typified by two investigators who had grown up in Europe but had then emigrated and been trained in North America: George Mandler and Endel Tulving.

KEY TERM

Verbal learning: A term applied to an approach to memory that relies principally on the learning of lists of words and nonsense syllables.

Gestalt psychology: An approach to psychology that was strong in Germany in the 1930s and that attempted to use perceptual principles to understand memory and reasoning.

In Britain, a third approach to memory developed, based on Frederick Bartlett's (1932) book *Remembering*. Bartlett explicitly rejected the learning of meaningless material as an appropriate way to study memory, using instead complex material such as folk tales from other cultures, reflecting his interest in social psychology and stressing the importance of the rememberer's "effort after meaning." This approach emphasized the study of the memory errors that people made, explaining them in terms of the participants' cultural assumptions about the world. Bartlett proposed that these depended on internal representations that he referred to as **schemas**. His approach differed radically from the Ebbinghaus tradition, relying on quite complex tasks but, as was the case with the later followers of Tolman and Hull, Bartlett was left with the problem of how to study these elusive inner representations of the world.

A possible answer to this problem evolved gradually during the Second World War with the development of computers. Mathematicians such as Weiner (1950) in the US, and physiologists such as Gray Walter (1953) in the UK described machines that were able to demonstrate a degree of control that resembled purposive behavior. During the 1940s, a Scottish psychologist, Kenneth Craik (1943), working with Bartlett in Cambridge produced a brief but influential book entitled *The Nature of Explanation*. Here he proposed the idea of representing theories as **models**, and using the computer to develop such models. He carried out what were probably the first psychological experiments based on this idea, using analog computers (digital computers were still being invented) and applying his computer-based theoretical model to the practical problem of gun-aiming in tanks.

KEY TERM

Schema: Proposed by Bartlett to explain how our knowledge of the world is structured and influences the way in which new information is stored and subsequently recalled.

Model: A method of expressing a theory more precisely, allowing predictions to be made and tested.

Tragically, in 1945 he was killed in a traffic accident while still a young man.

Fortunately, the new approach to psychology, based on the computer metaphor, was being taken up by a range of young investigators, and in the years following the war, this information-processing approach to psychology became increasingly influential. Two books were particularly important. Donald Broadbent's *Perception and Communication* (1958) developed and applied Craik's seminal ideas to a range of work carried out at the Medical Research Council Applied Psychology Unit in Cambridge, England, much of it stimulated by practical problems originating during the war. Some 9 years later, this growing field was then brilliantly synthesized and summarized by Ulric Neisser (1967) in a book whose title provided a name for this burgeoning field: *Cognitive Psychology*.

Using the digital computer as an analogy, human memory could be regarded as comprising one or more storage systems. Any memory system—whether physical, electronic, or human—requires three things, the capacity to *encode*, or enter information into the system, the capacity to *store* it, and—subsequently—the capacity to find and *retrieve* it. However, although these three stages serve different functions, they interact: The method of registering material or encoding determines what and how the information is stored, which in turn will limit what can subsequently be retrieved. Consider a simple physical memory device, a shopping list. If it is to work, you need to write legibly in a language the recipient shopper understands. If it were to get wet, the ink would blur (impaired storage) making it less distinct and harder to read (retrieval). Retrieval would be harder if your handwriting was poor (an encoding–retrieval interaction), and if the writing was smudged (a storage–retrieval interaction). The situation is further complicated by the discovery that our memories comprise not one, but several inter-related memory systems.

HOW MANY KINDS OF MEMORY?

As the influence of the cognitive approach to psychology grew, the balance of opinion moved

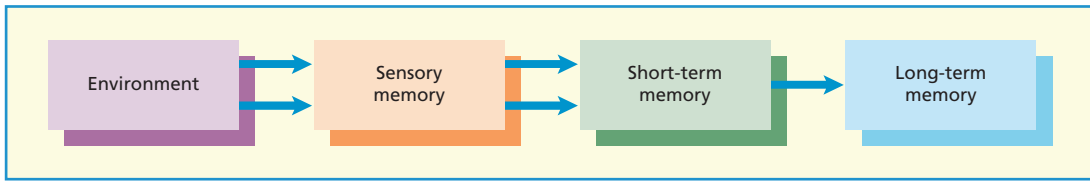


Figure 1.2 An information-processing approach to memory. Information flows from the environment through sensory storage and short-term storage to long-term memory.

from the assumption of a single memory system based on stimulus–response associations towards the idea that two, three or perhaps more memory systems were involved. Figure 1.2 shows the broad view that came to be widely accepted during the 1960s. It assumed that information comes in from the environment and is first processed by a series of sensory memory systems, which could be best regarded as providing an interface between perception and memory. Information is then assumed to be passed on to a temporary short-term memory system, before being registered in long-term memory (LTM). A particularly influential version of this model was proposed by Atkinson and Shiffrin (1968). It was dubbed the **modal model** because it was representative of many similar models of the operation of human memory that were proposed at the time. As we shall see, a number of the assumptions underlying this model were subsequently questioned, causing it to be further elaborated.

The question of how many kinds of memory remains controversial, some theorists object to the very concept of a memory *store* as too static, arguing instead that we should concern ourselves with *processes* (e.g. Nairne, 1990, 2002; Neath & Surprenant, 2003). They point to similarities across a range of very different memory tasks and suggest that these imply common processes, and hence a unitary memory system. Our own view is that we need to think in terms of both structures such as stores and the processes that operate on them, just as an analysis of the brain requires the contribution of both static anatomical features and a more dynamic concern with physiology. We should certainly look for similarities across domains in the way that these systems perform, but the presence of common features should not encourage us to ignore the differences.

Fortunately, regardless of the question of whether one emphasizes similarities or differences, the broad picture remains the same. In what follows, we ourselves use the distinctions between types of memory as a way of organizing and structuring our knowledge of human memory. As discussed below, we assume separate sensory, short-term and long-term memory systems, each of which can be subdivided into separate components. We do not, however, assume the simple flow of information from the environment into long-term memory that is suggested in Figure 1.2, as there is abundant evidence that information flows in both directions. For example, our knowledge of the world, stored in long-term memory, can influence our focus of attention, which will then determine what is fed into the sensory memory systems, how it is processed and whether it is subsequently remembered. Thus a keen football fan watching a game will see and remember particular plays that her less enthusiastic companion will miss.

We begin with a brief account of **sensory memory**. This was an area of considerable activity during the 1960s and provides a good illustration of the general principles of encoding, storage, and retrieval. However, given that it relates more to perception than memory, it will not be covered in the remainder of the book. Our outline continues with introductory accounts of short-term and working memory, before moving to a brief preliminary survey of long-term memory.

KEY TERM

Modal model: A term applied to the model of memory developed by Atkinson and Shiffrin (1968).