ALAN BADDELEY, MICHAEL W. EYSENCK,
AND MICHAEL C. ANDERSON

MEMORY

Third Edition

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MEMORY

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- the chapter on "memory across the lifespan" strengthens the applied emphasis, including the effects of malnutrition in developing nations on cognition and memory.

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MEMORY

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MEMORY

THIRD EDITION

ALAN BADDELEY

MICHAEL W. EYSENCK

AND MICHAEL C. ANDERSON

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"For Hilary"—Alan Baddeley

"To Christine with love"—Michael W. Eysenck

"To Max, whose toddlerhood I hope always to remember"—Michael C. Anderson

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ABOUT THE AUTHORS

As described in his recent memoirs, *Working Memories: Postmen, Divers and the Cognitive Revolution*, Alan Baddeley graduated in Psychology from University College London. He spent the following year in 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, the British Academy, the Academy of Medical Sciences, and the American Academy of Arts and 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 postdoctoral 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. He 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. His 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 THIRD EDITION

The current edition uses the same broad structure as the two previous editions, but with a somewhat clearer delineation of the various sections. I continue to be responsible for the two introductory chapters involving relatively modest changes, followed by the chapter on short-term memory which now contains more on visual short-term memory. The working memory chapter is updated in the light of recent developments including current attempts to compare and contrast different theoretical approaches. The chapters covering the basic study of long-term memory are all now covered by Michael Anderson, who provides a more coherent overview from someone who was very actively involved in recent advances in the area and its links to neuroscience. The chapter on learning has been significantly updated to include exciting work on retrieval-based learning, cortical plasticity, spacing learning, the impact of motivation on the neural mechanisms of encoding, divided attention, an expanded treatment of implicit forms of memory, and the latest cutting-edge developments of the cellular basis of plasticity. The chapter on episodic memory has been expanded to include coverage of the neural mechanism of episodic encoding and consolidation, and innovative work identifying the neural basis of schemas and how they enhance retention by hastening consolidation. The chapter on autobiographical memory now includes expanded coverage of emotional effects, new reports of severely deficient autobiographical memory, updated coverage of psychogenic amnesia, and the latest findings in the neural basis of autobiographical memory. The retrieval and forgetting chapters have been updated with recent developments in these area at the cognitive, brain systems, and cellular levels. Michael Eysenck continues to cover theory and research on semantic memory, which has increasingly benefitted from the approach of cognitive neuroscience. He also continues to cover chapters on the application of the study of memory beyond the laboratory to eyewitness testimony, prospective memory, and memory improvement, areas that have seen impressive advances in the years since the previous edition. He has however passed on to me the chapter on memory in childhood, which I have adopted as part of a three-chapter block on memory development and decline. I take a slightly more applied approach reflecting my interest in the effect of disease and malnutrition on early development and the potential contribution of the study of memory to practical aspects of child development. The memory and aging chapter contains more on recent attempts to minimize the effects of age on cognition. The third chapter in this section focuses principally on applied issues of memory decline with particular reference to Alzheimer's disease and to traumatic brain injury concluding by discussing methods to help people deal with failing memory.

Once again I am heavily indebted to Lindsey Bowes for her contribution at levels ranging from typing my mumbled dictation through helping search for references to rescuing me from frustrations induced by my very limited IT skills. I again am also grateful to my wife Hilary who continues to tolerate my refusal to behave like a sensible retiree.

I (Michael Eysenck) am indebted to my wife Christine in every way for her support for my time-consuming book-writing efforts. The completion of this book has given me more time to spend with our delightful grandchildren Sebastian and Clementine.

Michael Anderson is grateful to his partner Nami for her considerable support in enabling work on this text, and to his son Max, who illustrates daily the power of learning, and who has provided inspiration for many examples in this book.

Finally, we are grateful to the staff at Taylor & Francis for their overall management of the project. In particular we would like to thank Ceri McLardy and Kirsten Shankland for keeping us on track with their customary efficiency and good humour and to the Production Editor Pip Clubbs for her friendly efficiency during the final stages of producing the book.

Alan Baddeley
York, 2020

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CHAPTER 1

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. We forget more than computers, but we are likely to retain what is important and useful and forget unimportant details. We are good at rapidly encoding the context in which an event happens, what happened, when and where, so as to access when appropriate. We are good at remembering patterns of repeating events, a skill that helps us understand the world using this understanding to strip away redundant information and using the core meaning for future planning. Finally, we are very good at coping with forgetting by using knowledge to reconstruct partial memories. For these reasons, computer scientists are beginning to be interested in learning from human memory and importantly forgetting, with a view to potentially building some of these characteristics into computer memory (Mezaris, Niederee, & Logie, in press). Hence, despite their limitations our fallible memories play an absolutely crucial part in our ability to function independently in our complex world. Perhaps the most dramatic evidence for the usefulness of human memory comes from the plight of patients who have lost these capacities as in 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 four 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 declaring 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

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.

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 the social and neurobiological 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 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 ongoing 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 19th 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 systems but have a different way of using them?

So how can we move beyond introspection?

An answer to this started to develop in Germany in the latter half of the 19th 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

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

intensive series of experiments on himself over a two-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 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, a consonant-vowel-consonant nonword such as *zug pij* 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 US 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's general theory of learning based largely on the behavior of rats

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.

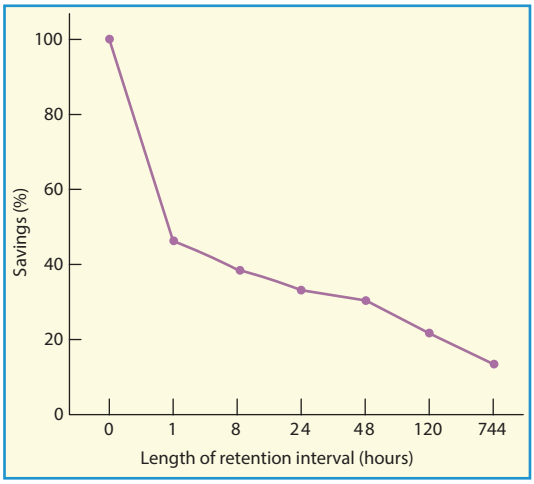

Figure 1.1 Forgetting over time as indexed by reduced savings during relearning. Data from Ebbinghaus (1885).

in mazes which was presented in an elaborate style based directly on that used by Isaac Newton in presenting his classic work, the *Principia*. However the various disputes between such theories appeared to reach deadlock in the late 1950s leading to their general abandonment. This allowed the more staid verbal learning approach, previously disparagingly discounted by its critics as "dust bowl empiricism," to attract a broader range of investigators interested in studying learning and memory. This in turn 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.

In Britain, a third approach to memory had developed, based on Frederic 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 that influenced the verbal learning approach, but left Bartlett with the problem of how to study these elusive inner representations of the world.

A possible answer to this problem evolved gradually during World War II 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. 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

KEY TERM

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.

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.

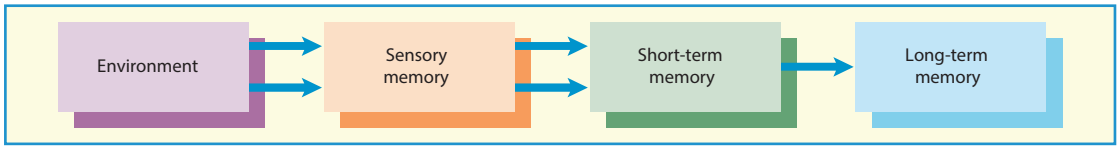

Figure 1.2 An information-processing approach to memory. Information flows from the environment through sensory storage and short-term storage to long-term memory.

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 nine 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 interrelated memory systems.

HOW MANY KINDS OF MEMORY?

As the influence of the cognitive approach to psychology grew, the balance of opinion moved 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. 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 be concerned with *processes* (e.g., Nairne, 1990, 2002; Neath & Surprenant, 2003). They point to similarities across a

KEY TERM

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