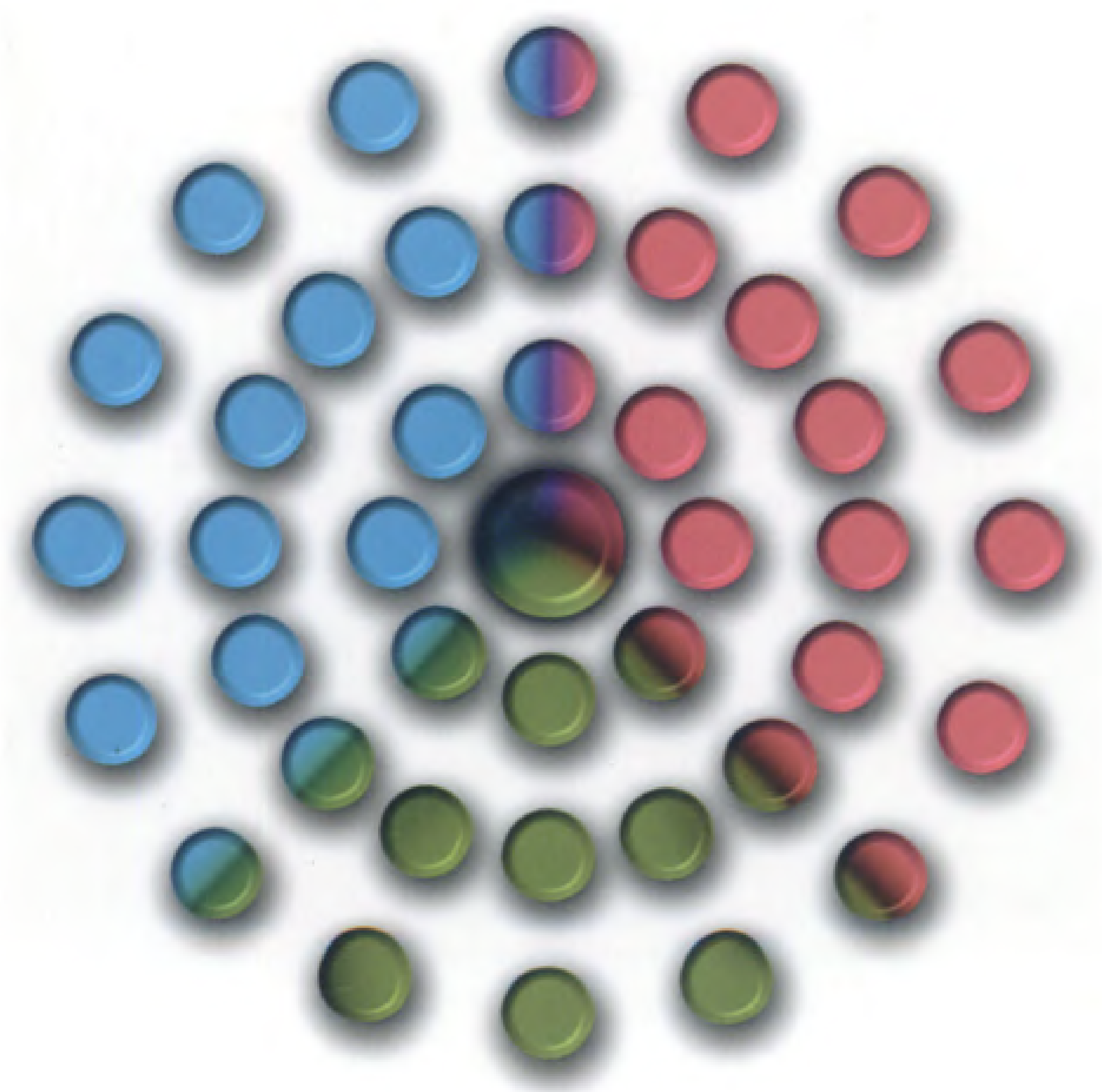
Attention, Perception and Memory

An Integrated Introduction

ELIZABETH A. STYLES

Psychology Focus



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Series preface

The Psychology Focus series provides short, up-to-date accounts of key areas in psychology without assuming the reader's prior knowledge in the subject. Psychology is often a favoured subject area for study, since it is relevant to a wide range of disciplines such as Sociology, Education, Nursing and Business Studies. These relatively inexpensive but focused short texts combine sufficient detail for psychology specialists with sufficient clarity for non-specialists.

The series authors are academics experienced in undergraduate teaching as well as research. Each takes a topic within their area of psychological expertise and presents a short review, highlighting important themes and including both theory and research findings. Each aspect of the topic is clearly explained with supporting glossaries to elucidate technical terms.

The series has been conceived within the context of the increasing modularisation which has been developed in higher education over the last decade and fulfils the consequent need for clear, focused, topic-based course material. Instead of following one course of study, students on a modularisation programme are often able to choose modules from a wide range of disciplines to complement the modules they are required to study for a specific degree. It can no longer be assumed that students studying a particular module will necessarily have the same background knowledge (or lack of it!) in that subject. But they will need to familiarise themselves with a particular topic rapidly since a single module in a single topic may be only 15 weeks long, with assessments arising during that period. They may have to combine eight or more modules in a single year to obtain a degree at the end of their programme of study.

One possible problem with studying a range of separate modules is that the relevance of a particular topic or the relationship between topics may not always be apparent. In the Psychology Focus series, authors have drawn where possible on practical and applied examples to support the points being made so that readers can see the wider relevance of the topic under study. Also, the study of psychology is usually broken up into separate areas, such as social psychology, developmental psychology and cognitive psychology, to take three examples. Whilst the books in the Psychology Focus series will provide excellent coverage of certain key topics within these 'traditional' areas, the authors have not been constrained in their examples and explanations and may draw on material across the whole field of psychology to help explain the topic under study more fully.

Each text in the series provides the reader with a range of important material on a specific topic. They are suitably comprehensive and give a clear account of the important issues involved. The authors analyse and interpret the material as well as present an up-to-date and detailed review of key work. Recent references are provided along with suggested further reading to allow readers to investigate the topic in more depth. It is hoped, therefore, that after following the informative review of a key topic in a Psychology Focus text, readers not only will have a clear understanding of the issues in question but will be intrigued and challenged to investigate the topic further.

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To my Mother, Gwen

Prologue

When psychology first began it was believed that it should be the study of conscious experience. The early psychologists such as William James (1890) appreciated the intimate relationship between attention, perception and memory, and produced some of the best subjective descriptions of the contents and operations of the mind. Even before James, other researchers attempted to measure the units of sensation that they believed made up the primitive units of experience. For many years the study of the contents of mind were abandoned as impossible to measure scientifically while the Behaviourist movement concentrated on stimulus–response relationships. However, in the middle of the 20th century, cognitive psychology began the scientific investigation of the internal processes that lay between stimulation and response. The first models in cognitive psychology included attention, perception and memory, but as research expanded, psychologists increasingly concentrated on smaller and smaller aspects of these. This was because it is too difficult to investigate all aspects of human cognition at once, and large problems and questions need to be broken down into small ones to make them possible to answer. Whilst this approach has led to great advances in understanding, it can sometimes lead to the important relationships between attention, perception and memory being played down. The development of connectionist and parallel distributed models in the last 20 years has begun to bring back the relationship between perception, attention and memory.

In this book I shall try to show that although a great deal can be understood about components of cognition in isolation, and although the brain has an organisation that is specialised, it must be remembered that the outcome of many processes are involved in producing coherent behaviour, and that we must not forget that attention, perception and memory are all involved in even apparently simple tasks. I have chosen to include sections on measuring sensation, hearing and touch, and cross-modal studies, as these are often not included in similar texts, and as we live in a multidimensional environment, I felt these topics were important. Of necessity I have omitted topics that others might think essential.

In the first chapter I shall outline some of the questions for psychology; the development of the cognitive approach and some of its assumptions are explained in Chapter 2. Chapter 3 is concerned with some of the early work on sensation and demonstrates that even the measurement of sensation can be influenced by other processes. It also shows that the relation between the physical world and the experienced world is neither simple nor reliable. This chapter also explains some methods that will be referred to in other chapters. The next three chapters are about visual perception, visual attention and recognising objects and faces. Although divided for convenience, these chapters involve attention, perception and memory for the visual world. Chapters 7, 8 and 9 deal with the world of sound, touch and pain, and attention to sounds, and then consider the way that information from vision, hearing and the other senses interacts in studies of cross-modal effects. As our interaction with the world involves the processing of information from all sources, it is important to understand cross-modal studies. Next, we shall consider how attention is involved in the control, planning and monitoring of behaviour, and

Chapter 10 considers how learning leads to skills and automatic behaviour, and how actions can go wrong. Finally, Chapters 11 and 12 deal with different types of memory and how knowledge about the past and the present is represented.

Chapter 1

Introduction

Chapter 1

WELL, HERE YOU ARE: sitting down, reading a book. Not really very remarkable, you might think—initially. What's more, the book is about cognitive psychology, a topic you might be expecting to find dull and hardly relevant to what people usually expect psychology to be about. Are attention, perception and memory really that important? If so, are they really as interesting as other aspects of psychology such as social interaction or developmental psychology? Let us consider this by asking some questions. How did you get hold of this book? Why did you decide to read it? Perhaps someone told you about it. How do you remember who told you? Would you recognise that person if you saw them again? How did you understand what they said to you? If you had to go to the library, how did you know what to do there, or how use the catalogue? How did you know what a bookcase looked like and how did you avoid walking into desks and other people on your route? How did you read the words on the spine of the book to see if they matched the title you remembered, and how did you manage to reach for the book you wanted rather than another book nearby? The answers to these few questions involve attention, perception and memory. Now, while you are reading, you are moving your eyes along the lines of text—effortlessly. You are paying attention to reading; you perceive the words and know what they mean because you have learnt them and they are stored in your memory. As you read on you may learn new things that will also become stored in memory, but how will you be able to recall what you have learned when it comes to the exam? Whether or not you do well in a test, I hope you will have gained some insight into the importance of attention, perception and memory for daily living.

As we go about our everyday business, we move about the world, recognise people and objects, make plans and actions, and remember what we did yesterday and what we must do today. The environment provides a rich source of sights, sounds and smells, and we perceive it all around us. We attend to parts that interest us, look around it, make actions in it and upon it. We can remember what we did and what we heard and who we saw some time later. In this complex environment we need to know who we are, where we are, what is around us and where things are in relation to each other and to us. We need to decide whether what we detect is important, and how we should respond to it. All these things seem so familiar, simple and effortless it would be easy to think there is little to explain—we just 'do' them. However, the way we are able to encode, interpret and respond to the complexity of stimuli around us does need explanation. This is an exciting and challenging task, and it is at the heart of the questions asked by cognitive psychology.

Let us take an apparently simple example. You step out into the garden on a sunny morning. You experience a world in which the flowers and shrubs are brightly coloured and the sun is warm on your back. There is the sound of birds singing; the wind rustles the leaves on the trees and brushes your hair against your face. The hum of traffic buzzes in the background. As you stand there, you catch the smell of last night's barbecue. You laugh again as the joke that your friend told you comes into your mind, and you try to remember the name of the person they brought with them, but fail. This shows that as well as sensing the external world via the sensory systems, this sensory information may also trigger internal events, or stored memories. All around there are sources of sensation, which are perceived, attended to and transformed by complex processing sequences to construct your total experience of the garden scene and all its associated memories. Somehow, the external physical world has been translated into what you are experiencing. The brain has produced an internal, mental representation of the physical world that enables you to see, hear, smell and feel it and remember events related to it.

Apart from being able to experience the world, we also act on the information it provides. If the mobile phone in your pocket rings, you automatically reach into your pocket and press the buttons necessary to answer it. As you talk, you walk around, avoiding obstacles. An insect lands on your face and you immediately make a rapid movement to brush it away. How do you know where to place each step, reach, what to press or where to brush your face? How much of this do you do without thinking? These are all questions addressed by cognitive psychology.

Curiously, if you *really* step out into the garden and do what I have just described, the experience you have is that the world really *is* 'out there'. It is not experienced as being inside your head, but as displayed around you. You can walk around in it, point to parts of it and touch other parts. In this example, I expect you will have imagined the experience. When you imagine something, knowledge is retrieved about previous experiences stored in long-term memory to construct what it would be like if you really were to do it. This construction is held in conscious memory while you think about it, or attend to it. However, when you are imagining the garden scene there really is nothing 'out there', so the image must be in your mind. Of course, in reality, the image of the scene is only in your mind in both cases. Cognitive psychologists are interested in discovering the processes that allow us to perceive and attend to the world around us as well as explaining how what we have learnt is used in making sense of what we find there.

The problem

Attention, perception and memory are central topics in cognitive psychology; if you look in any textbook on cognitive psychology you will usually find a separate chapter on each of them, together with chapters on other aspects of cognitive psychology. These chapters are usually subdivided into smaller sections, each looking at component processes and theories of different aspects of attention, perception and memory. This approach is taken to aid clarity of explanation, but in so doing, can give the impression that individual aspects of cognition can be understood in isolation from each other. However, it is always important to remember that to properly understand the role of any single aspect of cognition we must appreciate how that role is dependent upon and interacts with other aspects.

In this book I shall attempt to demonstrate that although we can consider attention, perception and memory as identifiable components of the human cognitive system, for a complete understanding of any of them it is necessary to appreciate the way they interact and depend on each other. I shall have to divide what is explained into chapters, but will try all the time to relate one to another, and demonstrate the interrelationships with everyday examples. We all know, at a subjective level, that unless we pay attention to something we neither perceive it nor remember it. 'Pay attention to what I am saying or you will not be able to remember it later!' 'I am sorry, I was not paying attention and did not see what you were doing.' These examples show what we all know; that attention leads to better perception and memory. However, these words do not explain anything. They are simply labels that represent what we do; they do not explain what is actually involved when we attend, perceive or remember. The challenge for cognitive psychologists is to specify fully and explain all the processes involved.

Attention, perception and memory

Although not independent, attention, perception and memory can be identified as different cognitive activities that are involved in identifiable aspects of cognitive behaviour. In the chapters that follow we go into the details of experiments, studies of patients and evidence from cognitive neuroscience that have refined our understanding of these fundamental concepts. Here I shall attempt to characterise what is meant by each term so that we can refer to them as we go along.

Attention

There are many varieties of attention, but in most cases it is involved in the selection of a subset of information for further processing by another part of the information processing system. Selection from a subset of the sensory input or sense data may be required for perceptual processing; we can call this '*attention for perception*', for example, looking at something to see what it is. Alternatively, selection of one or another form of response may be required; we can call this '*attention for action*', for example, do you want to take the call on your mobile? You will press different buttons depending on your decision.

Attentional selection is deemed necessary because the rest of the processing system cannot process all stimulus inputs or all response outputs simultaneously. Both these varieties of attention give it the role of an active agent that does something, i.e., selects. Alternatively, attention is described as a pool, or pools, of processing *resources* that can be allocated to perform cognitive tasks. The attentional resources can be allocated to a single task, and may have to be increased as the task becomes more demanding, or the resources can be divided between tasks according to individual task demands. For example, if the call you are taking is very important you may stop walking to devote all your attention to it. Here again, attention is an active agent; this time it does the information processing, rather than select information for processing elsewhere. When we need to maintain attention over a period of time to, for example, detect an intermittent signal appearing at a particular location, this involves sustained attention and vigilance. For example, you may have been intending to listen in case the phone indoors rings, but after a while in the garden you forget you should be monitoring for a distant sound. If we become tired or bored, maintaining this kind of task can be difficult. Attention may wander; we need to be able to keep our attention on the task at hand. The control of attention, either to determine what is to be selected or how to divide resources or maintain vigilance, also involves attention; in this case, executive attention is involved in the supervision of selectivity or resource allocation.

A rather different view of attention is that, rather than an active agent, it is the outcome of processing. Rather than a cause, it is an effect. This is related to the subjective experience of what is being attended as the focus of conscious experience. In this case, attention is not an active processing agent but simply an outcome of processing that allows us to 'know' what we are doing; we 'see' the object of attention. In one influential theory of attention, focal attention is used to bind visual features together into objects.

The relation between conscious experience and attention brings us to the distinction between processes that do or do not require attention. Most of the processing in the brain is not available to conscious inspection; it is unconscious and proceeds automatically, without requiring any attentional processes. Processes that require attention in some form or other are called controlled processes, while those that do not are called automatic processes. Even when we are attending consciously on a task, attention can be *captured* automatically by a sudden change in the environment. In this case the control of attention is dictated by unconscious processes.

Perception

The most general meaning of the term perception is sensory processing. The sense organs transduce physical energy from the outside world, which is encoded and delivered to the brain via sensory neurons for interpretation by the perceptual system. For example, the pattern of light on the retina is encoded by rods and cones; this data is transmitted through the pathways that deal with visual input and distributed to the cortical areas of the brain that are specialised for representing edges, colour, shape, location, movement, etc. Perceptual analysis is refined as it moves through the visual pathways. This information can be used to judge distance, specify the spatial layout of a scene, identify faces and objects, or guide eye movements or reaching. Most early stages of perceptual processing are automatic and unconscious. We prevent ourselves from knowing the colour of an object or the movement of a car as it goes past us. A more specific definition of perception refers to this conscious, or phenomenal, experience of seeing, hearing, touching, etc. We do not perceive a fragmented pattern of light, shade and edges, we 'see' a face or 'hear' a voice. In fact we 'see' a girl in a red car, going fast, in the distance. This is the perceptual experience that is the final output of perceptual processing.

Although the perceptual systems encode the environment around us, attention may be necessary for binding together the individual perceptual properties of an object such as its colour, shape and location, and for selecting aspects of the environment for perceptual processes to act on. For us to identify the information that represents the objects formed from perceptual data by attentional processing, that representation must be able to contact stored knowledge in the memory system.

Memory

The simple definition of memory is a store of information. It is a result of learning. However, psychologists have been able to distinguish many varieties of memory, with different capacities, that endure for different periods of time and store different kinds of knowledge information using different representations. Furthermore, some memories can be recalled into consciousness while other memories store knowledge that can only demonstrated by the performance of actions. In addition to the storage components of memory, psychologists must also identify and be able to explain all the operations involved in encoding information into memory and retrieving information from memory as and when it is required.

The duration of memory gives us one way of partitioning it. Very brief duration sensory memories, with high capacity and fast decay, act as buffers from which information selected by attentional processes can be encoded into a more durable form. Examples of these are iconic memory for visual information and echoic memory for auditory information. It is iconic memory that allows you to see the patterns made by sparklers on firework night. Each spark is very short-lived, but iconic memory holds the information long enough for it to be related to the movement of all the other sparks. Then there is short-term or working memory, which holds information arriving from perceptual processing and retrieved from longer-term memory stores while we perform ongoing tasks such as mental arithmetic or problem solving. This memory contains what we are currently thinking about, is limited in processing capacity, and remains active in consciousness as long as it is attended. We can appreciate the limitation by trying to multiply two large numbers, say 142 × 317, in our head. Most of our short-term memory is immediately used up in remembering the question. Once we try to do the multiplication and have to also remember the products, the capacity of memory is overloaded and we probably lose the very numbers we were trying to multiply! There appear to be separate short-term stores for visuospatial, verbal and auditory information. Apart from the storage components of working memory there is also an executive control system that can move information between stores; for example, naming the letter 'R' requires us to recognise it visually, but produce a spoken response. The central executive is also important in maintaining order and is involved in planning and decision making, so would be involved in keeping track of numbers used in a mental arithmetic problem.

The most durable long-term memory stores are the repository for all other stored knowledge. A major distinction is between semantic memory for facts, and episodic memory for personal experiences. Both semantic and episodic memory stores are declarative, which means we are able to tell someone else their contents. So, if I ask you 'Where is Paris?' you can retrieve the fact that it is in France, and may also know that it is the capital city. If you then go on tell me what the view was like from the top of the Eiffel tower when you went up it last summer, you are then retrieving and telling me about something from your episodic memory. Autobiographical memory is related to episodic memory and provides us with self-identity and our life history.

Other memories are not declarative—you are unable to explain them in words but can demonstrate them by actions. These memories are stored in procedural memory and specify how to do something. Although you know how to ride a bicycle you cannot explain to another person how you do it. It might be possible to describe some of the actions, such as 'get hold of the handlebars, put one foot on the pedal and scoot along until you are going fast enough to get on . . .' etc., but these instructions do not convey the knowledge necessary for successful cycling. Anyone may be able to explain how to ride a bicycle, but it would only be possible to find out if they really did 'know' how to do it by asking them to demonstrate this skill.

Another distinction between memory types, similar to the procedural/declarative distinction, is the difference between implicit and explicit memory. Again, people can learn and demonstrate knowledge implicitly, but without knowing they have that knowledge.

Another important issue in memory theory is the question of whether memory is better thought of as different stores or different processes. The argument here is that, depending on the kind of processing engaged in during learning, a different kind of memory will result. There certainly are many different processes involved in learning and memory, but the process account of memory has been difficult to prove. What is definitely true is that unless a stimulus is consciously perceived and attended to, it does not leave a memory trace that can be explicitly retrieved. However, there is evidence that stimuli that have not been attended and cannot be consciously recalled are able to affect subsequent processing. This is evident in studies of subliminal perception and in patients with amnesia, who show preserved learning from experiences they cannot recall.

The philosopher Kant (1724–1804) argued that the only things about which we can have knowledge are 'phenomena', and the physical world of real objects can only be known indirectly. MacPhail (1998) points out that as we do not perceive the external world directly, then 'in order to know what is "out there" we need to understand the nature of the transformations wrought upon it by our minds. And that is a psychological issue' (p. 63). The questions that modern psychologists attempt to answer have been around for thousands of years and have been debated by philosophers, but philosophers are not scientists.

Psychology, however, can be considered 'the science of mental life' (James, 1890), and as Miller (1962) points out, the key words are 'science' and 'mental'. In the example of stepping into the garden, the mental experience is evident, but to explain how this experience is arrived at is a question requiring scientific explanation. Before psychologists can begin their scientific study they must try to define aspects of mental life into smaller, manageable and potentially answerable questions, and to develop methods that allow them to measure and quantify components of 'mental life'. As psychology has evolved the questions asked and the methods used have changed, as we shall see.

Chapter 2

So what must be explained, and how can we find the answer?

chapter 2

Introduction

WHEN PSYCHOLOGY WAS FIRST FOUNDED, conscious experience was its central, most important area of enquiry. Wundt (1873) said that one of the principal aims for psychology was to investigate consciousness, which he saw as standing between the internal and the external world. Some of Wundt's other aims were to investigate the physiological conditions of conscious events and to try and understand human existence. For Wundt, and his student Titchener, psychology was the scientific study of immediate experience, and therefore consciousness, which was the 'totality of experience at a given moment'; just like your experience when you stepped (or imagined stepping) into the garden. Other early psychologists, including William James and Sigmund Freud, also saw the study of consciousness as the heart of what research in psychology should be concerned with.

In the early days of psychology, the preferred method for discovering the basic elements of conscious experience was *introspection*. Introspection involves the subjective examination of mental contents and introspectors had to reduce their experience into the most basic elements and carefully avoid what Titchener called the 'stimulus error', which was the imposition of meaning or interpretation onto the stimulus. Of course, this is what we normally do. We 'see' a tree, not a pattern of colours, shapes and intensities distributed in time and space. Titchener's introspection attempted to avoid any interpretations based on learned categories or concepts that are usually the basis for our everyday interpretation of the world. He was trying to separate perception from attention and memory. However, it will become evident that the interaction between sensory data and stored knowledge is an essential process in cognitive psychology. Today the distinction between *bottom-up* sensory-driven processing and *top-down*, knowledge-driven processing is involved in many cognitive explanations, and is central to understanding the relationships between attention perception and memory.

Early psychologists liked the idea of being able to explain consciousness in terms of fundamental neural mechanisms such as excitation and inhibition, but the danger they saw was that if consciousness could be reduced to neural processes, then psychology would be neurology and have no place of its own in science—so they rejected this way of accounting for consciousness. Today, new computational modelling techniques are able to explain some psychological processes in terms of excitation and inhibition, that is, similar to neural processes. These *connectionist* or *parallel distributed processing* accounts of cognition will be discussed later, and are believed to be powerful because they are based on similar principles to those on which neurons in the brain operate.

In the early to mid 20th century, psychology became the study of 'behaviour', conscious experience was believed to be an impossible area of study, and introspection was disregarded as an unreliable source of data. The Behaviourists, as they were called, for example Watson (1916) and Skinner (1938), took the view that only observable behaviour should be used as data. They believed that only stimulus inputs and response outputs could be objectively observed, and that it was not scientific to talk about unobservable, hypothetical stages such as attention, perception or memory, in the way we do now. The study of internal mental processes and consciousness was unscientific as it could not be objectively measured. However, it became increasing clear that not all behaviour could be explained in terms of stimulus and response, in particular how the same stimulus could give rise to different behaviours, or how humans could control complex situations. A new approach was needed, and in the mid 1950s the approach we now call cognitive psychology began to dominate research into psychology as it allowed psychologists to study scientifically the hidden processes that operate between a stimulus and a response. In the following sections, the cognitive approach and its development will be explained. More recently, psychologists have become increasingly interested in consciousness again and are beginning to give accounts of cognition and consciousness that are entirely based on neurological events. This view is not a threat to psychology today and psychologists work together with neurologists, neuroscientists, radiographers, computer scientists, cognitive neuropsychologists and others in a combined effort to understand the brain and how it gives rise to our astonishing capabilities, including conscious experience. Marcel (1988) says, 'Psychology without consciousness, without phenomenal experience or the personal level, may be biology or cybernetic, but it is not psychology' (p. 121).

Cognitive psychology and the cognitive approach

In the preceding paragraphs I have used the term cognitive psychology without defining what it means, and as yet have not attempted to define attention, perception or memory. First let us consider what we mean by cognition and cognitive psychology, and then turn to the individual terms. Basically, cognition means knowing about something; it is the act of knowing. Cognitive psychology, therefore, is the branch of psychology that is concerned with understanding how it is we come to know about things, how we are able to make sense of the world around us and interact with it in a meaningful way. It is hard to improve on the definition given by one of the most important contributors to the development of cognitive psychology, Ulric Neisser. In his book *Cognitive Psychology*, Neisser (1967, p. 4) explained that 'cognition refers to all the processes by which the sensory input is transformed, reduced, elaborated, stored, recovered and used. It is concerned with these processes even when they operate in the absence of relevant stimulation, as in images and hallucinations. Such terms as sensation, perception retention recall, problem solving and thinking, among many others, refer to hypothetical stages or aspects of cognition'. We can include attention amongst the other processes not specifically mentioned. Neisser goes on to say that 'Given such a sweeping definition, it is apparent that cognition is involved in everything a human being might possibly do; that every psychological phenomenon is a cognitive phenomenon'.

Human information processing

In the preceding quotations Neisser refers to *hypothetical stages*; these are stages of information processing that are hypothesised to be necessary to perform a cognitive task, and arise from the distinctive approach used by cognitive psychologists in trying to understand the hidden workings of the mind. Early psychologists such as Wundt and James had studied cognitive psychology inasmuch as they were concerned with the conscious experience of what was known to the person introspecting, but they were not able to study processes that took place at unconscious levels.

In 1958 Broadbent proposed a new conception of human performance in terms of information processing, and together with the work of others at the time, this view led to what we can call the birth of cognitive psychology. This new conception of the mind allowed early cognitive psychologists to begin to consider the unobservable, hypothetical, internal processes that were believed to underlie all cognition.

Varieties of processing

Although everything we do can be considered cognitive, not all cognitive processes are the same. When considering how to partition human information processing into hypothetical stages, there are processes that can be considered to involve selecting a particular location of the environment or aspect of the sense data for further processing; we could think of these as involving attentional processes. Other processes may be concerned with encoding information at the attended location and could be considered perceptual processing. Then again, recognising what the attentional and perceptual processes produce would involve matching the incoming data to representations of knowledge stored in memory. As explained here, these different processes appear to be distinct operations, and would seem to proceed in a sequence of stages; attend, perceive, recognise. Because cognitive psychologists take the view that the human information processing system is similar to any system that processes information, they have adopted the computer metaphor for attempting to understand and model cognition. So, in addition to the subject matter of cognitive psychology, it also adopts a distinctive approach in trying to understand how we operate. The human being is thought of as an active processor of information. This information may arrive as sense data, or be generated internally from stored knowledge. Information is processed in different ways by different information processing systems to enable us to, for example, attend, perceive or remember. Some information is consciously manipulated, as for example in mental arithmetic. Other processing takes place outside conscious awareness; for example, when you say 'hello' to a friend you recognise, you are only aware *that* you recognise them, not *how* your brain enabled you to recognise them. Similarly, when you produce the word 'hello', you cannot explain how you found the word, or how you moved your vocal apparatus to pronounce it.

The computer metaphor

Following the acceptance that information processing underlies cognition, the computer is now widely adopted as the most promising metaphor for modelling and understanding human cognition, and computer technology has developed, so the sophistication and usefulness of the metaphor has increased. Initially computers were slow, limited-capacity, serial devices, not very similar to the human brain. Modern computers, however, are fast and parallel with enormous computational power, much more like our own computer, the brain. One advantage of the computer metaphor is that it has suggested, by analogy, a number of hypotheses about human information processing. When designing a computational device it is better to have one component that analyses the input, one that stores information in a memory buffer, another that executes particular subroutines depending on the input, a memory for previously entered information and so forth. However, despite advances in computer technology, we are different from most computers. We are animate, rather than inanimate beings, we can move around our environment and act upon it, we can catch a ball and throw it back; not only do we respond to environmental stimuli, we can also modify them.

In writing computer programs, or attempting to analyse the steps and stages involved in a cognitive task, flowcharts are often produced that specify the operations necessary to achieve a particular goal. The flowchart is a sequence of interconnected boxes and arrows, and each box on the chart represents a component process or stage of the overall task that must be completed before the next stage can be moved to. In Broadbent's 1958 model (see Figure 2.1) you can see these hypothetical stages quite clearly.

Although this model is most frequently described as a model of attention, it also includes perception and memory. One advantage of a flowchart is that its boxes specify what needs to be computed in order for a particular behaviour to be achieved. However, questions such as what moves along the arrows that connect the boxes and how this takes place must not be ignored. Another problem is that there is a danger of forgetting the importance of the interaction between stages of processing. Whilst Broadbent's model includes attention, perception and memory in the same model, the drive to understand the workings of each component part has led to psychologists specialising in the study of attention, perception or memory. This

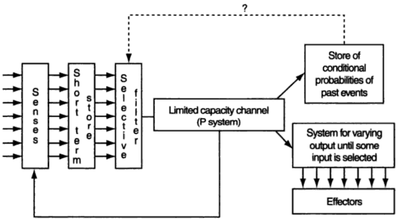

FIGURE 2.1 Broadbent's (1958) model of human information processing. From Broadbent (1970).

specialisation is necessary because it is impossible to experiment on all aspects of the processing system at the same time, and within each area research has focused down even further to answer more specific questions. However, it is important to remember that the fully functioning brain will be attending, perceiving and remembering all at once, with each component contributing to 'mental life'. Let us consider the important interaction between attention, perception and memory.

Bottom-up and top-down processing

Broadbent (1958) initially proposed that most cognitive processing proceeds in a staged sequence. On the presentation of a stimulus, perceptual processes act on the input, then attentional processes transfer some of the perceptual information to a short-term, transitory memory store, then if the material is *rehearsed*, it could be translated into a more permanent long-term memory. A sequence of processing stages that proceeds from sense data to further stages is called *bottom-up*; however, our expectations of what the sense data contains can influence the way we interpret it *top-down*. Bottom-up processing is said to be stimulus-driven because it is directly affected by the stimulus input. On the other hand, top-down processing is said to be conceptually driven as it is affected by existing knowledge derived from past experience. An example of top-down processing would be listening to a conversation in a noisy room. Although the sound stimulus is degraded and incomplete, our knowledge of language allows us to complete what we fail to hear, top-down, and follow the conversation quite easily. Most cognition involves this interaction between stimuli and stored knowledge, and demonstrates that the hypothetical stages of attention, perception and memory must be interactive during cognitive activities.

Experimental psychology

Experiments are carried out to test hypotheses derived from a theory. In a typical experiment the psychologist will design a task that is intended to manipulate a variable affecting one hypothetical stage of processing and will then measure response time or accuracy to determine the effect of that variable on performance. For example, the ability of the participant to select information from a visual display may be manipulated by providing a cue as to where in the visual field the target will arrive. Posner (1978) found that a brief light flashed at the location where a target subsequently appears will speed the detection of a target, but if the cue is in the wrong location the participant cannot ignore the flash and is therefore slower to respond to the target. This experiment on visual orienting of attention will be discussed in detail when we look at visual attention. Another example, in the area of memory, is that the number of items that can be remembered in the short term is limited to the number of 'chunks' rather than the absolute amount of information. (Miller, 1956). Although measuring cognitive performance in controlled laboratory conditions is not the same as observing cognitive performance in the uncontrolled natural environment, it can be argued that the control that experiments impose has allowed the identification of many fundamental cognitive processes. Experimental psychologists have developed many of the basic paradigms that examine cognitive processes at the behavioural level. Throughout this book we shall see that the experimental paradigms, the theories they were designed to test and the results they have discovered have been applied by other psychologists using other methods of investigation. These other methods, discussed in later sections, include cognitive neuropsychology, computational modelling, and cognitive neuroscience. Different methods approach the problem of cognitive psychology at different levels of analysis and explanation.

Levels of explanation

Marr (1982) believed that theories need to be defined at different levels of analysis to provide a complete and overarching account of intelligent behaviour. He argued that there are three levels of explanation to be considered.

1 The implementational level, i.e., the 'hardware' that does the job.

2 The algorithmic level, i.e., the set of procedures or rules that need to be carried out by the hardware in order to achieve the required computations.
3 The computational level, i.e., what the system actually needs to compute in order to achieve the purpose for which is designed.

To make these levels clear, Marr used the analogy of a cash register in a supermarket. Over the years, cash registers have changed substantially. Initially they were entirely mechanical devices with series of ratchets that clocked up numbers and were worked by hand; later they became electronic, and now we have the laser bar code readers that derive the cost of each item! So, although at the hardware or implementational level these machines are different, at the computational level they do exactly the same thing, i.e., add up your shopping bill. The algorithm used by the machines may also be different, but not necessarily. Experimental cognitive psychology and cognitive neuropsychology are interested in the algorithmic and computational levels, while cognitive neuroscientists, physiologists and neuroanatomists are concerned with the hardware, or underlying brain and neural mechanisms. Increasingly these initially different disciplines are working together, along with computational modellers and philosophers to provide explanations of cognitive behaviour at all levels, and are informing each others' ideas in the way Marr suggested.

Modularity of mind

The sort of computer we are most familiar with, a PC, is made of components that work together to achieve a particular task such as word processing, playing games, surfing the net and so on. These different tasks run on the same computer, but require the use of different programs and components in different combinations at different times. Nevertheless, it is possible to specify what is required and when. Although we accept that all the parts are necessary, the designer can produce one part of the system in isolation, provided it is specified how that part interfaces with the others so that the output from one component can communicate with the remainder of the system. In this sense we can identify components of human information processing, but the psychologist must also specify the ways in which the outcome of processing in one system affects and is affected by the other systems.

One of the most important assumptions in psychology today is that the human brain is modular. This assumption stems from the very influential ideas of Marr (1976) and Fodor (1983). In a modular system, large and complicated computations are achieved by lots of 'modules'. These modules perform particular processing operations on particular domain-specific kinds of information. Together they form the whole system, but each module acts as an independent processor for its own particular purpose. Fodor (1983) argues that modules are innately specified, hard-wired and autonomous, in that the functioning of the module is not under conscious control. In a modular system the failure of one module does not prevent the remaining modules from working. Such a system would seem advisable in terms of survival; we would be severely disadvantaged if damage to one small part of the brain resulted in all of the rest of the undamaged brain ceasing to work. Not only is a modular system a sensible design, but there is good evidence that when patients suffer local damage to particular brain regions, only certain computational functions are lost.

Cognitive neuropsychology

Not only is a modular system based on a good design principle, but evidence from neuropsychological patients who have suffered brain damage supports this assumption. Damage to one part of the brain may lead to the loss of one function, such as the ability to recognise faces, but leave the ability to read and recognise words intact. This dissociation between the processing of different stimuli supports the idea that one module is responsible for face processing while another is responsible for reading. However, it could simply be that reading is less difficult than recognising a face, so if another patient with different brain damage can be found who shows the reverse pattern of behaviour, i.e., who can read but not recognise faces, then a double dissociation is found. This is strong evidence for the independence of the processes underlying reading and face recognition. Studies of patients suggest that there is a meaningful relationship between the location of brain damage and the function that is lost. Work by cognitive neuropsychologists on people who have lost particular abilities can help to clarify models and theories of normal cognitive functioning. Any model or theory must be able not only to account for normal behaviour, but also to explain what has gone wrong for the patient. In the flowchart approach to modelling cognition, it is often the case that the patient appears to have lost the processing capability of one box of the flowchart, or that the information is not able to flow from one stage to another—as if an arrow has been lost. Throughout this book we shall meet a number of examples where neuropsychological evidence has furthered our understanding of normal cognitive processing. *Cognitive neuropsychology* provides evidence that the brain appears to break down as if it were a modular system.

Computational modelling

Since the beginning of cognitive psychology as a distinct approach to psychology, researchers have tested their ideas and models of human behaviour using computational modelling. We shall meet a variety of these models in different chapters. Some of the earliest models were semantic networks, such as that of Collins and Quillian (1969), which were devised to help understand how knowledge is represented and can be retrieved from *semantic memory*. Another kind of model is a *production system*, and in Chapter 9 we shall consider Anderson's ACT*, with respect to learning skills. In production systems, rules for the operation of a procedure are represented as IF–THEN rules, so IF a set of conditions are present in working memory, THEN the rule is applied. These systems are also useful for modelling logical cognitive processes such as reasoning and problem solving, but we shall not consider these cognitive processes here. The most recent computational techniques use *connectionist* networks, or *parallel distributed processing* models. The power of these models is that rather than having to be explicitly programmed, the networks can learn and to some extent program themselves. Another property of connectionist models is that they are composed of elementary units or nodes that are highly interconnected and have excitatory and inhibitory connections between them. In this sense they are more like the brain than previous models. The complexity of connectionist models is outside the scope of this book, but we shall meet some early versions of this type in their application to pattern recognition and knowledge representation.

Cognitive neuroscience

Over the past few years technological developments have allowed psychologists to actually 'see' the working human brain in action. Techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), magneto-encephalography (MEG) and event-related potentials (ERPs) can be used to discover important information about the brain's activity during cognitive tasks. It has become possible to see where and when particular brain areas become active during task performance. This information, as suggested by Marr when he discussed levels of explanation, has contributed to and constrained theory-building in cognitive psychology. With the techniques of *cognitive neuroscience*, psychologists do not have to rely on the breakdown of ability following brain damage in neuropsychological patients, but can observe the workings of the intact brain.

Evidence shows that the human brain is made up of millions of neurons that intercommunicate with each other via numerous connections, tracts and pathways that feed backward and forward through the brain to form a highly interconnected, complex system. The brain receives information from the sense organs and stores a vast amount of knowledge gained from past experience. By combining selected data from the outside world with stored knowledge, the component parts of the brain work together to produce coherent and purposeful behaviour. So, although we may think of attention, perception and memory as being independent in terms of the chapters in a book, in reality they cannot be entirely independent because of the nature of the human brain.

Cognitive neuroscience is concerned with bringing together a deeper understanding of psychology using modern techniques of brain imaging, which allow us to see the brain at work; using data from neuropsychological patients who have selectively lost abilities they once had; modelling psychological processes using computers; and traditional experimental psychology. A good overview of the approaches to cognitive psychology can be found in Eysenck and Keane (2000), and an introduction to cortical functions and brain imaging in Stirling (2000).

Summary

Early psychologists believed that introspecting on the contents of consciousness could provide evidence, but this method was rejected as too subjective and replaced by Behaviourism, which rejected the study of mind. The new approach of cognitive psychology provided a model of the human mind as an information processing system that could be considered to process information in a similar way to a computer. Within this approach it became possible to analyse the processing components that were necessary to perform cognitive tasks and to proposed hypothetical stages for experimental investigation. Early models and theories of human information processing incorporated perceptual, attentional and memory processes and appreciated their interaction. Theories can be defined at different levels of explanation, and advances in cognitive neuropsychology, cognitive neuroscience and computational modelling can aid understanding at different levels. Although the mind is generally considered to be modular, and although attention, perception and memory are different components of the cognitive system, they do not work in isolation; the cognitive tasks they perform are complementary and interactive.

Self-assessment questions (Solutions on p. 319)

1 What is introspection and what are its disadvantages?
2 What is the information processing approach and what are its advantages?
3 Distinguish between top-down and bottom-up processing.
4 Give two characteristics each for attention, perception and memory.

Further reading

Eysenck, M. and Keane, M. (2000) *Cognitve psychology: A student's handbook* (4th ed.). Hove, UK: Psychology Press. See Chapter 1 for an overview and more detail of the cognitive approach.

Gross, R. and McIlveen, R. (1999) *Perspectives in psychology*. London: Hodder and Stoughton. A useful introduction to the history of psychology.

Jarvis, M. (2000) *Theoretical approaches to psychology*. London: Routledge. A useful introduction to the history of psychology.

Chapter 3

Sensation

Chapter 3

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Jan W. de Fockert, *Department of Psychology, Goldsmiths College, University of London.*

Although attention, perception and memory can be identified as separable components of the human cognitive system, this book argues that for a complete understanding of any of them it is necessary to appreciate the way they interact and depend upon one another. Using evidence from experimental psychology, cognitive neuroscience and neuropsychological patients, aspects of attention, perception and memory are related together. Written by an established author, this text clearly explains and evaluates key theories and puts different approaches to this field in context and will be of interest to first and second year undergraduates studying psychology and cognitive psychology.

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