HUMAN THINKING

THE BASICS

Human Thinking: The Basics provides an essential introduction into how we develop thoughts, the types of reasoning we engage in, and how our thinking can be tailored by subconscious processing.

Beginning with the fundamentals, the book examines the mental processes that shape our thoughts, the trajectory of how thought evolved within the animal kingdom and the stages of development of thinking throughout childhood. Robertson insightfully explains the effectiveness of political slogans and advertisements in engaging shallow information processing and the effortful, analytical processing required in critical thinking. Delving into fascinating topics such as magical thinking in the form of religion and superstition, fake news, and motivated ignorance, the book explains the discrepancy between reality and our internal mental representations, the influence of semantics on deductive reasoning and the error-prone, yet adaptive nature of biases.

Containing student-friendly features including end of chapter summaries, demonstrative puzzles, simple figures, and further reading lists, this book will be essential reading for all students of thinking and reasoning.

S. Ian Robertson gained his PhD from the Open University, UK, on 'Problem Solving from Textbook Examples'. He has published work on portable computing as well as articles and books on problem solving. He was the Head of the Department of Psychology at the University of Bedfordshire from 2001 to 2014 when he retired.

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PREFACE

Although we all have experience of it, like other concepts such as consciousness or intelligence, defining thinking is not all that easy. Merriam-Webster dictionary defines it as: 'the action of using one's mind to produce thoughts'. It allows us to interpret the world, solve problems, make decisions, present an opinion, make predictions, and achieve our goals. While we are aware of thinking as a conscious activity, it can also encompass unconscious processes since it is the product of 'mental events' that generate our awareness of both the world around us and of our internal state. It does not take place in a vacuum: we are embedded in a world and the particular environment, including the culture, in which we currently find ourselves dictates the course of our thoughts and actions, influenced in turn by our individual personal experiences, personalities, motivations, prejudices, current goals, and so on. What we have learned about the world, and hence what beliefs we have, plays a major role in how we think and behave. Some types of thinking are fast and immediate – you can recall someone's name without being aware of how you retrieved it from memory, or recognize a dog effortlessly without having to work out what it is. Another type of thinking is slow and deliberate and sometimes effortful, such as analyzing accounts or translating from one language to another. To regard thinking as simply conscious awareness, particularly of what is going on in our heads as we solve problems or reason about the world, is therefore to skip over some important antecedents of this awareness – the wellspring of our thoughts.

This book therefore takes a broad view of what constitutes thinking to include how both conscious and unconscious mental events influence or govern our behaviour. We can consciously decide to do A rather than B, but what underlying processes pushed us to make that particular decision? What, for example, is someone thinking when they put money in a slot machine, or vote for a president, or buy a car? A discussion of human thinking necessarily covers the interplay between two kinds of thinking: the effortful, analytical, sequential, slow kind where we are consciously trying to work something out or think things through; and the spontaneous, automatic, intuitive, fast kind that allows us to get things done without having to spend time on them unnecessarily. At the same time, it can be difficult to balance the positives and negatives that result from different aspects of human thinking. A person can show intelligence and rationality by analyzing data, reaching objectively accurate conclusions, and making predictions. That same person may also show irrational biases or intolerance of other people's views. Where do these differences in thinking come from?

The book is divided into four parts covering different aspects of thinking, although with a degree of overlap. Part 1 provides an overview of what human thinking entails and some of its evolutionary origins. Part 2 looks at thinking as reasoning as we attempt to find a useful or valid solution to a task, real or imaginary, or to analyze an argument. Part 3 looks at those occasions when our thinking is motivated, and sometimes led astray, by biases of different kinds. Part 4 discusses further the motivations behind our cognitions and the role of beliefs and evidence in influencing our thinking.

PART 1

THINKING: WHAT IS IT AND WHERE DOES IT COME FROM?

1

WHAT IS 'THINKING'?

INTRODUCTION

It is important to realize that the world we live in is ‘out there’. Our minds are separated from it and gain knowledge about it through our senses. Shock waves propagate through the air, strike our ears, are recoded into electrical impulses, and passed on into the rest of the brain which interprets them as sounds, words, and music. Parts of the electromagnetic spectrum strike our eyes and various subsystems in the retina convert this light into electrical impulses that get passed on to various centres in the brain generating ‘vision’ which, in turn, is an interpretation of our surroundings. Other sensors in the skin and deeper in the body detect touch, cold, heat, pain, various tastes, smell, proprioception (the sense of body movement and position such as where your right leg is right now) and others – a great deal more than five. These electrical impulses in the neurons (nerve cells) of the brain and central nervous system generate our internal model of the external world – a virtual reality model. In the words of Deutsch (1997), ‘All reasoning, all thinking and all external experience are forms of virtual reality’ (p. 121). It has to be a pretty accurate and extremely useful model otherwise you would not be able to navigate through the world and we would not have survived so long as a species. That said, it can differ in some respects from person to person. Some might see a snake and feel fear and flee whereas someone else might recognize the snake as a pet. These are different interpretations of the same stimulus. Furthermore, our senses and our memories can, under certain conditions, be deceptive.

CONSCIOUS VS UNCONSCIOUS THINKING

Human thinking manifests itself in many ways. It's what goes on in our heads when we:

- Try to solve a problem;
- Daydream;
- Plan what to do;
- Make a decision;
- Develop an opinion or belief;
- React to an event or person;
- Categorize something or someone;
- Consider what might have been;
- Learn a complex sequence of behaviours;
- Perform a complex sequence of behaviours without thinking.

That last example might seem self-contradictory but it's there as a reminder that some of our thinking is conscious and some unconscious, and that conscious thought is subject to influences that we are not always aware of. For example, repeating a sequence of actions over and over can lead to *automaticity*. Learning to read is effortful but once learned it becomes automatic. You can't, for example, stop yourself from reading the first word in next sentence. Automatic behaviour, including habits, is very useful as it allows you to engage in a complex sequence of actions without the necessity of thinking about each individual action in the sequence. Thus, you can drive a car while paying attention to the news or make a cup of tea while daydreaming about that nice young man you met the other day. The knowledge gained from habitual or automated sequences of actions such as riding a bike is known as *procedural* knowledge ('knowing how' to do something). Procedural knowledge isn't really correct or incorrect but rather it is more or less useful in attaining a goal. Knowing how to ride a bike or how to find a TV channel can be useful. Procedures also include rules for attaining a goal. For example, a procedural rule might be; 'if the goal is to determine whether someone is female, then check to see if their hair is long'. It might be useful much of the time but that's not guaranteed.

A second way in which our conscious thinking is influenced is through innate pressures. Some of them tend to be reflex actions: blinking when something approaches the eye, babies suckling and grasping objects, and their intuitive knowledge of physics such as the effects of gravity. Other examples of seemingly innate knowledge or automatic responses include smiling, cooperation, child rearing, and the 'four Fs': feeding, fighting, fleeing, and mating. Third, feelings and emotions in general can influence conscious thought including: fatigue, illness, mood, the effects of drugs, stress, fear, excitement, pain, and embarrassment. Finally, you can't think unless you have something to think about – your thoughts have some content. We are influenced not only by the situation we find ourselves in but also by the information stored in our memories. Some of this information is general knowledge (2 × 6 = 12) or *semantic* knowledge and can be contrasted with *episodic* knowledge (I recall sitting in a restaurant in Dubrovnik at this time last year). Episodic knowledge is remembering what you had for breakfast this morning, semantic knowledge is knowing what 'breakfast' means. Together these two constitute what is known as *declarative* knowledge ('knowing that' something is the case). Furthermore, declarative knowledge can be either correct or incorrect. You might 'know that' the earth is flat, but you would be wrong.

Thinking is therefore an interplay between what you perceive to be going on in your immediate environment and the knowledge you have allowing you to predict and interact with that environment. Recognizing the chair on the left in Figure 1.1 is almost immediate for people brought up in a western culture. However, unless you are familiar with Japan, it might take a little time to recognize the object on the right as a chair.

Figure 1.1 Chairs: Immediate recognition depends on the culture you are familiar with.

THINKING HAS ITS LIMITS

Have a look at Box 1.1.

Although I asked you to add 2 + 4, you didn't. You just said '6' because it is over-learned, and the answer is pre-stored in our heads. 2 + 4 triggers the answer 6. This is an example of simple *stimulus-response* learning – you don't know where the answer came from, it just appeared in your consciousness triggered by the stimulus '2 + 4'. You know the answer came from your memory, but you were not aware of the process by which you accessed it. 'It is the result of thinking, not the process of thinking, that appears spontaneously in consciousness' (Miller, 1962, p. 56).

BOX 1.1 SIMPLE PROBLEMS

Here are a number of simple problems. Go through each one and try to solve them, while at the same time trying to assess where the information you are using is coming from.

Add 2 + 4
Add 28 + 43
Multiply 43 × 28
Multiply 433 × 288

When asked to add 28 and 43, you were probably aware of something going on consciously in your mind. There are various ways in which you could come to an answer but in each of them you would trigger partial answers without obvious calculation (e.g., 2 + 4 and 8 + 3), and then you would have to store those answers temporarily before combining them. You have 2 + 4 in the 'tens column' if you like, giving 6 tens (60) and 8 + 3 gives 11 which you then add to 60 to give 71. Here, you are using the unconsciously accessed information that popped into your head and then consciously manipulating that information. But then again, some of you might have come up with 71 without much conscious thought at all.

The third sum is likely to be more taxing and involves processing the figures and storing several temporary answers or *sub-goals*. For example, one sub-goal might be to find the result of 3 × 8. Another might be to decide the best way to tackle the problem in the first place. There are strategies you might choose from such as attempting long multiplication in your head while trying to keep the results of the sub-goals in mind at the same time. You might try 40 × 28 first, then 3 × 28 and add them, and so on. If it's not the kind of activity you are used to, you may even find that your mind seems to run out of space to complete the calculation.

As for the fourth sum, if you were trying to do it in your head using the method of long multiplication you learned at school you would be struggling.

The point of that little exercise is that:

- over-learned items or behaviours can come to mind automatically;
- some activities require conscious manipulation of information;
- we need to be able to store information temporarily;
- finally, and perhaps most importantly, our thinking takes place in a kind of workspace known as working memory (WM) and WM has a limited capacity – there's only so much information it can manipulate at any one time, so this kind of thinking is effortful and slow.

Our thinking can also be affected by failing to access the memory we are looking for even though we know we have it (the so-called *tip-of-the-tongue phenomenon*). Or we may access information that is not actually helpful to solve our current problem. When we are sitting an exam, we may remember that the bit of information we need is at the bottom of the left-hand page of the textbook, but we can't remember what it actually says. We had no intention of remembering which part of the page it was on yet that's what has stuck. Context can have a big influence on what we can recall (Godden & Baddeley, 1975).

UNDIRECTED THINKING

Unlike other forms of thinking, daydreaming is not directed towards a goal (although one can daydream intentionally). We all do it. Allowing our mind to wander is easier than concentrating. While it is possible to talk aloud while solving a problem – essentially describing the current active contents of WM – you can't do that with daydreams. You can express what you have *just* thought about but not what you are *currently* thinking as that would disrupt your daydream. When you ask someone 'what are you thinking about?' you are asking them to tell you about the topic they are thinking about, not usually about what goal-directed sequence of mental operations they are currently consciously aware of.

When people are given demanding tasks to do, certain areas of the brain 'light up', particularly in the frontal lobe. At the same time, there appears to be another network of regions in the cortex whose activity reduces when we concentrate on a task. When it is over, and there is nothing further requiring attention, this 'default' network comes back online, hence its name: the *default mode network* (DMN; Raichle & Snyder, 2007). It seems to be able to jump between one mental state to another without much effort and to link to personal episodic memories in particular, allowing us to think about the past and use it to predict the future in the form of daydreams. However, when we concentrate on something, we are using an executive control network that is not so richly connected. To get anything demanding done, the executive control network has to make an effort to submerge the default network. There are therefore these two contrasting types of thinking that appear to be mediated by different brain regions: focussed thinking directed towards a task, and undirected, the kind that takes over when we are trying to get some work done and we find ourselves staring out the window daydreaming instead.

INATTENTIONAL BLINDNESS

A different phenomenon can occur when your attention is closely directed towards some activity, such as trying to keep track of an object in a constantly changing scene. When your attention is engaged in this way, you might not notice something out of the ordinary such as a gorilla walking past beating its chest. Simons and Chabris (1999) asked people to watch a now famous video in which there were three basketball players in black T-shirts and three in white T-shirts. While watching, they were asked to count the number of times the players wearing white shirts passed a ball between them as they moved around and among the players wearing black shirts. Only about half noticed a woman wearing a gorilla suit walking on, beating her chest, and walking off again. The authors referred to this as *inattentional blindness*. Focussing attention can also lead to *change blindness* where people don't notice that some aspect of the scene in front of them has changed or is changing right in front of them. For example, someone might watch a video of a jogger who stops and bends over to tie her shoelaces. She stands back up and continues to run and the viewer is completely unaware that she is now wearing different shorts.

THINKING AS INFORMATION PROCESSING – SOME HISTORICAL BACKGROUND

Thinking involves the manipulation – the processing – of information. To take a very simple example, a woodlouse will walk on its 14 legs until it reaches an obstacle. Using mainly its right legs, it might then turn left and carry on until it reaches another obstacle. Because its right legs are the last ones to move when an obstacle was reached, it's now the turn of the left legs to move to enable it to turn right. By doing this, it ends up zig-zagging in one general direction rather than, say, wandering around in a circle. The woodlouse is using a simple *algorithm*, a rule, that makes use of information from the environment – it can't go any further, so it tries to turn 90 degrees. When it encounters another obstacle, it uses information from motor memory – its right legs moved last time this happened so the left legs move this time.

Human beings obviously have a much, much larger and vastly more complicated structure (our brain) to deal with much more complicated kinds of information processing. However, when we look at the history of the psychological study of thinking and behaviour, the first half of the 20th century was dominated by behaviourist psychology which saw no reason to study actual thinking. Behaviourists were more interested in overt behaviour under specific external circumstances. So, faced with a particular stimulus (S), an organism would produce a specific response (R) (see (a) in Figure 1.2). The likelihood of an organism producing such a response would increase over time through *operant conditioning* (Skinner, 1988) – principally using some sequence of rewards known as *positive reinforcement*. Skinner used animals such as pigeons and rats in cages where there was either a button or lever that the animal would peck or pull as it moved around the cage, and a pellet of food would appear. The animal would then learn that pecking the button or pulling the lever would produce a food pellet. In these cases, the animals are exhibiting naturally occurring behaviours in that rats can press things and pigeons can peck things, and those naturally occurring behaviours were 'shaped' by the experimenter.

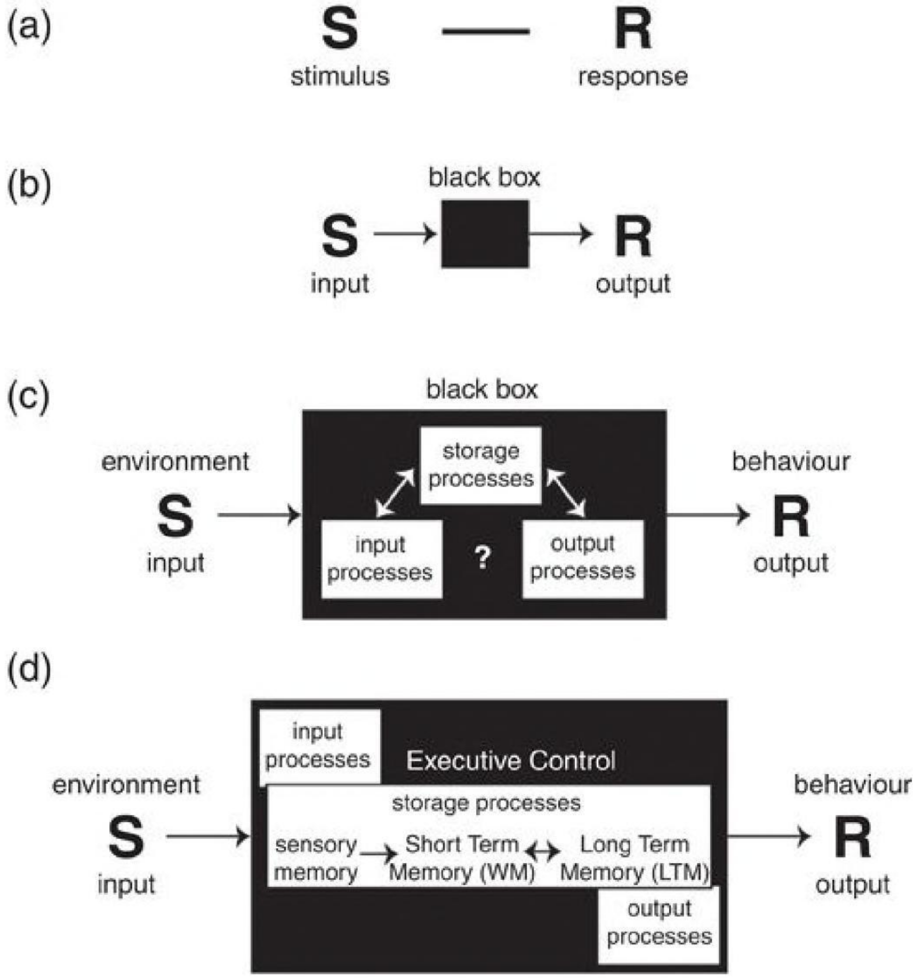

Figure 1.2 The development of putative structures in the mind that produce behaviour given a particular external environment.

So, what happens when the experimenter outside the cage starts manipulating the availability of food pellets when the pigeon pecks the button? A *fixed-ratio schedule of reinforcement*, such as a one in four ratio, means that the pigeon would be reliably rewarded with a pellet of food only after a certain number of button presses – once every four presses, for example. The reward, the reinforcement, is predictable. A *variable-ratio schedule* of one in four means that the delivery of a pellet is unpredictable. It might be after 2 presses or 6 presses. This turns out to be particularly effective at producing a high rate of responding because the animal doesn't know when it's next going to receive food. It is an example of how a strong habit can be formed that is very hard to modify subsequently as can be seen in the behaviour of people using fixed odds betting terminals and one-armed bandits in pubs, betting shops, and casinos. Furthermore, obtaining food or winning money stimulates the reward centres of the brain and increases levels of one of the brain's chemical messengers, the neurotransmitter dopamine.

While the behaviour of animals in laboratories has been manipulated by experimenters and the behaviour of gamblers is manipulated by betting companies, other forms of behaviour can be reinforced without our necessarily being aware that we are either being manipulated or are manipulating others. For example, a child who is whining or having a tantrum and demanding attention is very likely to get the attention she wants from the harassed parent just to keep her quiet. Thus, the child's behaviour is being reinforced – rewarded – by the parent: in order to get attention, whine. The wily parent can change the child's behaviour, in theory, by ignoring the child during tantrums and then attending to the child when she is quiet. Thereby, the calmness is being rewarded rather than the shouting.

In information processing terms, the stimulus is an input and the response is an output (see (b) in Figure 1.2). This form of *associative learning* is important in producing simple habits and automatic responses to the environment. While behaviourists wanted to ignore the 'hyphen' in Stimulus-Response (S-R) psychology, other psychologists, particularly from the 1950s, argued that there must be something going on – some form of mental events – to mediate between the input and the output. What, then, is going on inside the 'black box' that produces the overt behaviour? A conversation such as:

S: Are you coming to the cinema?
R: Yeah, whatever.

is not readily explicable using S-R psychology. The response, for example, may never have been uttered by the respondent before to that question so it's not a behaviour that has been reinforced. Some other explanation is needed to cover more complex behaviour than S-R psychology can manage, learning one's native language being one example, as Noam Chomsky famously pointed out in a critique of Skinner's book 'Verbal Behavior' (Chomsky, 1959). Not only can people make and respond to utterances they have never heard before, but children manage to learn a language without their utterances being reinforced. For example, when children are trying to express the past tense in English, they learn implicitly that there are rules such as adding '-ed' to a word – 'snowed', 'followed', 'folded'. They often then add '-ed' to words such as 'go' to produce 'goed' which they will not have heard and cannot have been rewarded for uttering.

Part (c) in Figure 1.2 provides a very basic architecture of what must be going on. There needs to be a structure or set of structures that can *decode* the information coming in. If someone is speaking to us in a language we understand, the unbroken stream of sound that gets converted from vibrations to electrical signals in the ear somehow gets parsed into individual words. We also access the meanings of those words as well as the meaning of collections of words in sentences or phrases. In order to do so we must have some kind of memory store of word meanings (a *semantic code* or *semantic representation*). Along with that there must be some kind of *syntactic code* or representation that determines how words can be combined, and a *pragmatic code* that allows us to understand what the goal of the utterance is. Some examples are shown in Box 1.2.

BOX 1.2 MENTAL REPRESENTATION OF UTTERANCES

Jeff is kneading some dough when there is a knock at the door. 'The door's open,' he shouts. What does he mean?

Ekaterina is in the hallway when her son comes in from the outside bringing with him a cold, wintry blast. 'The door's open!' calls his mother loudly. What does she mean?

Professor Worrell finishes her lecture by saying that the topic is complicated but remember 'My door's always open'. What does she mean?

The sentence 'The door is open' refers to the state of a door when it is a particular position. However, as well as knowing the meaning of the statement we also need to know why it is being uttered (the pragmatics).

'Me, Tarzan'.

We know what the words mean and what the whole phrase means despite it lacking a grammatical structure. We also know that it is meant as an introduction to someone who doesn't know him.

''Twas brillig, and the slithy toves did gyre and gimble in the wabe' (Lewis Carroll, Jabberwocky, 1871)

Here we can tell which words are nouns, which are adjectives, and which are verbs without knowing the meaning of any of the words. This demonstrates the fact that we have a mental syntactic representation of sentence structure.

'Colourless green ideas sleep furiously' (Chomsky, 1957, p. 15).

Chomsky is demonstrating that you can form a grammatically correct sentence with meaningful words but ones that make no sense. You cannot form a meaningful semantic representation of the sentence.

'The hills are alive with the sound of music'.

We seem to be able to accept this sentence as if it meant something even though hills aren't alive and tend to quite quiet places.

Part (d) in Figure 1.2 shows a development of the early information processing models where various stages in the flow of information can be experimentally tested. How long does sensory memory last? How much can we store temporarily in short-term memory (STM)? How is long-term memory (LTM) structured? How is central 'executive' control managed? And so on.

METAPHORS OF THOUGHT

There have been various metaphors, often linked to the technology of the time, that have been used to help us understand the mental events that constitute thinking. For example, Sigmund Freud used a hydraulic model of the mind to understand how repressed thoughts and feelings could manifest themselves in dreams and neurotic behaviours (Freud, 1954). This was like a fluid in a pipe being compressed and hence spurting out somewhere else. An early information processing model saw the mind as an early telephone exchange where input processes were like subscribers ringing the exchange where the operator would connect to the subscriber by plugging a cable into a socket in the exchange and asking what number they wanted. The operator would then connect the subscriber to the number by plugging another cable into another socket. The mind was the telephone operator passing information from input to output. But that doesn't explain how the operator works.

In the second half of the 20th century, computers provided a much richer model of how thinking might work. Instead of having a model that had unexplained gaps such as the telephone exchange model, computers were virtual machines that could perform a variety of different tasks depending on the software installed. Thus, a single machine can be a word processor, a calculator, a designer, a chess player, a movie player, a car driver, and so on. Descartes (1637/1998) regarded a person as a machine animated by an insubstantial soul (a 'ghost in the machine'). By distinguishing software from hardware in a computer, suddenly the ghost and the machine could be combined. Furthermore, a computer works by performing computations. Vision works by computing light intensities; from that – computing lines, edges, curves; from that – computing planes and surface orientations; from that – computing 3D volumes (Marr, 1982). So far, this type of computation involves serial, *bottom-up processing*: the results of one process passes to the next stage that computes an output that passes to the next stage, and so on. However, stored knowledge will kick in to help vision identify what it is looking at and where it is (*top-down processing*). This allows us to process multiple sources of information at the same time thus speeding up the task of identifying objects, understanding speech, flying aeroplanes, or whatever.

MENTAL MODELS OF THE WORLD

Processing information to generate a virtual reality model of the world usually means generating a series of mental representations. If you are planning where to go on holiday then you are generating a number of mental representations about what kind of holidays one you want, what kinds of activities you want to engage in, what kind of weather you are hoping to have, where you want to stay, how much you want to pay, how to get there, the timings involved. If the mental representation is complete, then the virtual reality model you have generated in your head should conform broadly to the actual reality that you will experience in the world, and problems that might arise can be solved before you even start. By mentally representing the world, you can plan your holiday, design a house, prepare what to say at an interview – all before actually going on holiday, building a house or taking part in the interview. We are able to do this because our experience of the world has allowed us to learn what to expect and thus predict the near future. The ability to represent the world is due to the fact that our brains are 'prediction machines' (Clark, 2013; Hinton, 2017a).

RELATIVE VS ABSOLUTE THINKING

There are many examples from decision making to risk taking to perception, and so on, that show that our thinking is relative rather than absolute. Figure 1.3 is an example from visual perception. We tend to make local comparisons rather than absolute ones. This is true even at a physiological level. For example, if you have three bowls of water, one hot, one cold and one at room temperature and you put one hand in the hot water and one in the cold water and hold them there for a short while, then take them out and plunge them in the water at room temperature, the hand that was in the cold water will find the room temperature water hot whereas the other hand will find it cold. Relative to the temperature of the water in the first bowl, the perceived temperature in the room-temperature bowl is cold or hot. Similarly, if you are poor, €100 is a lot of money. If you are rich, €100 is pocket money. If you are buying a house, you might offer €305,000 but just to make sure you could up it to €308,000. Another €3,000 is a relatively small fraction of the house price. For any other purchase that you might make, €3,000 is a lot of money.

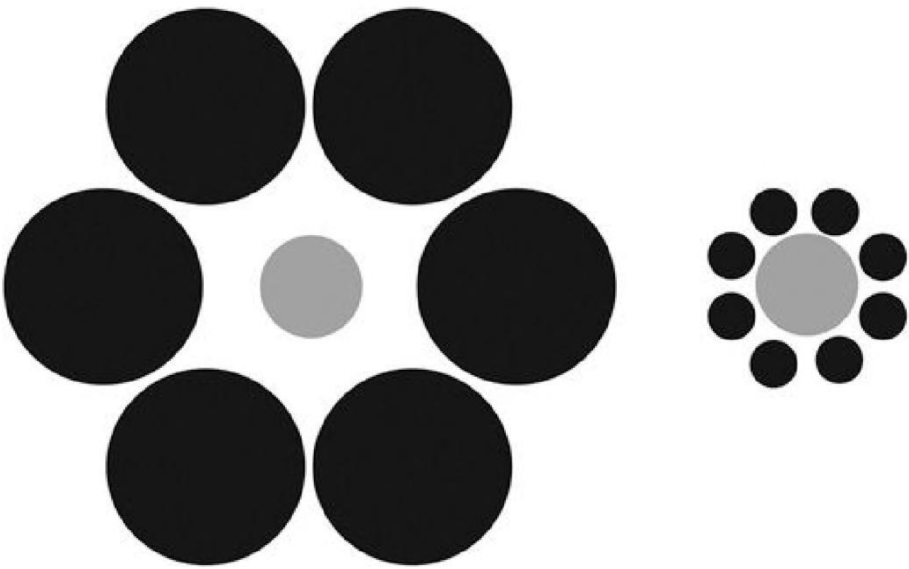

Figure 1.3 Effects of judgements of size of the grey circle due to the context. It is small relative to the large black circles and large relative to the small ones. They are, however, identical.

The ease with which something comes to mind makes it seem relatively important (see Chapter 5). If there is a report of a child dying due to an infection caught at an open farm where animals are handled, parents might think twice about going on an outing to an open farm and choose the beach instead. Thus, the visit to the farm seems relatively more dangerous than driving to the beach. However, such infections are exceptionally rare whereas car accidents are very common.

THE ROLE OF THE ENVIRONMENT

The environment can provide useful information to aid our thinking or generate constraints that limit what we can do. If you are sitting round a table at a meeting, there are several constraints on your behaviour that both the physical and social environment dictate. When travelling, the physical layout of streets or buildings or forests will determine how we get from point A to point B. If you have to get to the train station 10 miles away and you don't drive, don't feel like walking, and you are not on a bus route, then call a taxi. In this case environmental constraints make the decision simpler (see Chapter 3).

The environment can also provide useful information that guides our actions. For example, the redness of strawberries indicates that they are edible. A cave represents a place for shelter for an animal or a human. Whatever we have in the fridge might dictate what we have for dinner. The money we have dictates what kind of car we can afford. We are also surrounded by buildings, machines and technological gadgets that often try to ensure that their use is 'obvious'. The term *affordances* has been used to refer to the perceived use or action that one can perform when presented with an object (Norman, 1988). For example, the handle on a teapot 'affords' picking it up from there. A flat plate at one side of a door 'affords' pushing the door. A bar on a door can be either for pulling or pushing. A light switch affords pressing. In these cases, the objects themselves make clear what action is required without our having to think about it. A door with a bar that has a sign saying 'PUSH' is a badly designed door. I have found myself in a lecture theatre with a bank of light switches that had a set of instructions above it (one of which was incorrect). That is wrong in so many ways. There is also a social and cultural environment that prescribes certain behaviours and proscribes others. Together these influences can determine, at least to some extent, how we think about actions, objects and the behaviour of others. In short, the environment provides a great deal of information that can guide our thinking. Hence, the behaviour of the woodlouse and the human is imposed or strongly influenced by the environment.

FAST VS SLOW THINKING

Much of our behaviour is based on past experience, beliefs or intuitions that constitute rules of thumb known as *heuristics*. We may not be aware of where these have come from, but they will generally produce quick decisions that are normally correct and useful, otherwise this kind of behaviour would not have evolved. Such 'fast and frugal' thinking generally governs much of our daily behaviour. However, we are also capable of careful sequential analysis of decisions or problems we are faced with. This kind of analytical thinking is effortful and can be time consuming. These two types or systems of thinking have given rise to dual-processing theories of reasoning. This has a long history. For example, William James in the 19th century discussed 'associative' and 'true' reasoning, the first being an emotional, intuitive or gut-feeling and the second analytical, explicit and conscious. Here is an example from his book Principles of Psychology from 1890:

> 'Suppose I say, when offered a piece of cloth, "I won't buy that; it looks as if it would fade," meaning merely that something about it suggests the idea of fading to my mind, – my judgment, though possibly correct, is not reasoned, but purely empirical; but, if I can say that into the color there enters a certain dye which I know to be chemically unstable, and that therefore the color will fade, my judgment is reasoned' (James, 1890/1950, p. 341).

More recently these two modes of reasoning have been referred to as System 1 and System 2 (Stanovich & West, 2000) or alternatively Type 1 and Type 2, (Evans, 2010; Evans and Stanovich, 2013). Evans and Stanovich have argued that referring to two systems gives the impression that they are cognitively or neurologically based. They are rather qualitatively distinct types of processing that may be underpinned by several cognitive or neurological systems. For that reason, I will be referring to Type 1 and Type 2 but many authors continue to refer to System 1 and System 2.

According to Daniel Kahneman: 'System 1 operates automatically and quickly, with little or no effort and no sense of voluntary control. System 2 allocates attention to the effortful mental activities that demand it, including complex computations. The operations of System 2 are often associated with the subjective experience of agency, choice, and concentration' (Kahneman, 2011, pp. 20–21). In William James' example, the first response to the cloth is an intuitive response generated by Type 1. Decisions made via Type 1 are often heuristic. Such decisions, as James suggests, may well be correct and are very useful in that they allow fast decisions based on what might appear superficial evidence. There are times, though, when such heuristics can bias our reasoning and hence it is useful to have a second system that can override it using a more careful analysis of the situation to