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CHAPTER 1

Introduction

1.1 Preview of Chapter

We live in a complex environment, where new technological developments regularly challenge our wits. With the development of the Internet, the amount of information that is available has increased exponentially over the last decade. It is therefore essential that we improve our understanding of the way people learn to cope with these challenges. In the last century or so, a tremendous amount of information has been acquired regarding learning in psychology, neuroscience, education, sociology and other fields, with a substantial portion derived from research into expertise. The aim of this book is to review the most important results stemming from this line of research and to evaluate their implications for society. In particular, we will be interested in the educational methods that have benefited from expertise research and in the implications that this research has on how society can develop ways to help citizens cope with these new challenges.

A good way to start is to illustrate, with a few examples, what we mean by experts. A list of top-level experts would include Wolfgang Amadeus Mozart in music, Marie Curie in science, Magnus Carlsen in chess, Bill Gates in business and Jessica Ennis-Hill in sports. A list of more ordinary experts would include a physician, an engineer, a lawyer but also a baker, a florist and a nurse.

From the outset, we face a few central questions on the nature of expertise. The most obvious is: what is expertise? We will spend some time discussing some of the many definitions that have been proposed and evaluating the extent to which they are successful. This will lead to a working definition that we will use in most of this book. Another important question relates to the reasons why it is important to study expertise. We will see that there are both basic scientific reasons and more applied ones. However, before we address these questions, we need to clear up an important issue about the dual meaning of the word "expertise".

1.2 The Dual Meaning of the Term "Expertise"

Whatever the detail of the definitions, which we will consider in the next section, one must recognise from the outset that the term "expertise" has

two basic meanings, which are not necessarily consistent with each other. For example, the *Oxford Talking Dictionary* (1998) defines expertise as "Expert opinion or knowledge; know-how, skill, or expertness in something". The first part of the definition emphasises knowledge or even opinion – *knowing-that*. The second part emphasises skill – *knowing-how*, as indeed mentioned in the definition. This is a fundamental divide reflected in several of the fields we will consider in this book. On the one hand, sociology, law and – to some extent – philosophy are more interested in the first part of the definition (knowing-that). On the other hand, psychology, neuroscience and education essentially use the second part of the definition (knowing-how). Interestingly, some languages such as French accept only the first meaning of the term "expertise" in everyday language.

These two meanings raise the irksome question as to whether they are related, and indeed whether it makes sense to devote a book to expertise as a single concept. This book will argue that this is not only a meaningful endeavour but also an important one. Bringing together traditions of research that have focused on either meaning of the word will help integrate two bodies of knowledge that have essentially evolved independently. It also raises new and important questions that will spur new research and bring about new applications.

1.3 Definitions of Expertise

Having cleared up the question of the two basic meanings of "expertise", we can consider some of the definitions of expertise that have been proposed in the literature. Note that not all definitions neatly fit with the two meanings we have just discussed.

Intuitively, the term "expertise" brings to mind individuals such as physicians, engineers, chess masters and lawyers. Most people would also consider that good examples of experts are offered by the pundits (such as academics, journalists or business consultants) who proffer their views about their area of expertise (and even sometimes well beyond) on TV/radio and in newspapers. But what about occupations such as bricklaying and cigar making, or abilities such as language and walking, which most people carry out fluently? Obviously, some activities are more likely to be labelled as "expertise" than others. Is this reasonable or is it just a reflection of the prejudices of our society?

In research papers, expertise is often defined using experience and the amount of time an individual has spent in a domain. Unfortunately, while the amount of dedicated practice predicts expertise fairly well (see Chapter 8), experience in itself is often a poor predictor of true expertise (Ericsson et al., 1993; Meehl, 1954; Richman et al., 1996). Everybody knows amateur tennis players or pianists who fall short of expert performance despite having practised their favourite activity for years. In fact, there is direct empirical evidence from research on clinical expertise (Meehl, 1954) and chess (Gobet et al., 2004)

indicating that the correlation between expertise level and the number of years spent in a field is weak.

Another reasonable approach is to use diplomas: PhDs, honorary titles and certificates from official professional associations. There are at least four weaknesses with this approach. First, diplomas are often based not only on an objective measure of performance but also on sociocultural criteria. Second, diplomas often do not test the skills that will be used later, but rather test declarative knowledge. This is the case, for example, in medical schools and most fields in universities (psychology is a case in point). Thus, future medical doctors are tested on their knowledge of anatomy, biochemistry and pathology, and not on their ability to diagnose and treat patients. Third, unless detailed grades are supplied, diplomas do not provide much information about the skill level obtained. Fourth, some individuals can be experts without formal qualifications. A striking example is provided by Epstein (1996), who showed that some AIDS activists had acquired considerable knowledge about microbiology and statistics, which, added to their knowledge of AIDS culture, allowed them to make substantial contributions to research. As Gallo, who co-discovered the human immunodeficiency virus (HIV) and who was originally lukewarm to AIDS activists' work, put it: "It's frightening sometimes how much they know and how smart some of them are" (Epstein, 1996, p. 338).

Some fields offer more reliable measures of expertise, measures that are also ecological, in the sense that they are part of the culture of the domain. Researchers of business expertise can use the wealth accumulated by different individuals; students of expertise in science can use the number of citations that scientists have accrued during their career; and researchers of writing expertise can use the number of books an author has sold. While having the advantage of being quantitative, these measures have shortcomings as well. In particular, they can be sensitive to factors unrelated to expertise, such as market fluctuations in business, popularity of a specific school of thought in science and fashion in literature.

In an ideal world – at least for scientific research – experts would be rank-ordered as a function of their level of expertise, or even better, they would have their expertise quantified. When absolute measures are involved (e.g. time to run 100 metres or the amount of weight that an athlete can lift), there is no debate, barring accusations of cheating. Rank ordering is used in sports such as football, where the International Federation of Association Football (FIFA) publishes a monthly ranking of national teams, using a rather byzantine formula. Tennis uses the ranking of the Association of Tennis Professionals (ATP): the sum of the best 18 results from the immediate past 52 weeks. From the point of view of expertise research, the ATP rating has two weaknesses. First, it measures skill only over the last year, and second, it only takes points won in entire tournaments into account and ignores the strength of the opponents as well as the outcomes of specific matches.

The best available system so far is the Elo rating (Elo, 1978), developed for measuring chess skill but now also used in other domains such as Scrabble and

table tennis. The Elo rating takes into account both the outcome of a game (win, loss or draw) and the skill level of the opponent. It can be used after each game or match, producing a finely graded and up-to-date measure of skill. It also has the advantage that it is based on a sound mathematical model. Having such a quantitative measure is a real bonus, and this in fact partly explains why a considerable amount of research has been carried out on chess expertise. While researchers in most other domains of expertise have to satisfy themselves with coarse comparisons between novices, intermediates and experts, chess researchers can differentiate between a grandmaster with 2,620 Elo points and another with 2,680 Elo points, and even compute the expected outcome of a game between those two players.

Some researchers emphasise that expertise is something that can only be acquired with effort and intentionally, with a clear goal in mind (Bereiter & Scardamalia, 1993). This seems an unnecessary requirement. How expertise is acquired is of course important, but it does not seem wise to include this in a definition. Similarly, whether somebody is talented or not in a specific domain should not be part of the definition of expertise, not least because there is considerable disagreement about this question. We shall take up these issues in Chapters 7 and 8.

In a similar vein, it has been proposed that the hallmark of experts is that they display fluid behaviour, requiring few conscious decisions (Dreyfus & Dreyfus, 1988; Fitts, 1964). We shall see that this description captures expertise in some but not all situations. Moreover, it should also be pointed out that almost the opposite definition of expertise has sometimes been proposed. Bereiter and Scardamalia (1993, p.11) argue that "the expert addresses problems whereas the experienced nonexpert carries out practiced routines". A similar view is shared by Ericsson et al. (1993), who argue that just performing routine actions hinders the development of expertise, and that experts must deliberatively practice selected components of their skill. We will discuss this idea in considerable detail in Chapter 8 when dealing with *deliberate practice*.

The importance of knowledge has often been emphasised, in particular when human expertise is compared to the expertise (or the lack thereof) of computers. For example, it has been proposed that expertise is made possible by the acquisition of a large number of domain-specific patterns. While this is true in many domains (see Chapters 2 and 3), it seems prudent to not include putative *mechanisms* in the definition of expertise, in part because the nature of these mechanisms is still the topic of vigorous debate. In any case, investigating expertise will require reflecting on, and questioning, long-held views about the status of knowledge in cognition. An important question will be the link between knowledge and real-time cognitive processing. In intelligence research, these two forms of cognition are called *crystallised* and *fluid* intelligence, respectively (Cattell, 1971).

Based on the seminal work of de Groot (1965), who asked chess players of various skill levels to find the best move in a given chess position, Ericsson has repeatedly emphasised (e.g. Ericsson, 1996a; Ericsson & Smith, 1991a)

that expert performance should be replicable in the laboratory, when tasks representative of the domain are used. For example, when studied in the laboratory and compared to non-experts, chess experts should find better moves, physicists should provide better solutions to physics problems and medical doctors should provide better diagnoses. As we shall see in this book, this is in fact what has been found in the three examples just given, and indeed in most (although by no means all) domains of expertise. Thus, Ericsson's requirement seems a valid one, at least with domains where it is feasible to set up laboratory tasks that are ecologically valid. But this is not always possible. A counter-example is expertise in developing novel and ground-breaking scientific theories in physics; by definition, such events are rare, and thus unlikely to be captured in the laboratory.

Finally, we would be remiss to not mention some definitions where the social aspects of expertise play a central role. These definitions emphasise that "expertise" is a label that society or other groups give to individuals, sometimes irrespectively of the real competences of these individuals. Support for this view comes from the fact that selection criteria differ from one domain to the next, and indeed even differ within a domain (Sternberg, 1997). Labels can be official, such as university and professional titles, or informal, such as the label of the "local technology wizard", but this is immaterial when it comes to societal recognition. Stein (1997) argues that the term "expertise" can only be used within a specific context. According to him, it is incorrect to say that expertise resides solely in the expert: while individual knowledge and skills are obviously important, these gain their meaning only within the context provided by the social system of which the expert is a part. We will take up these issues in Chapters 11 and 12 when dealing with the social aspects of expertise and the sociology of professions.

In most of this book, we will define an expert as somebody who obtains results that are vastly superior to those obtained by the majority of the population. This definition has the advantage that it can be applied recursively and that we can define a *super-expert*: somebody whose performance is vastly superior to the majority of experts (Gobet, 2011).[1] This definition also has the advantage of providing a means to deal with domains where most individuals have a high level of natural ability (e.g. language, walking). It is still possible to identify an expert in language (e.g. somebody who possesses a large vocabulary) and an expert in walking (e.g. somebody who has won an Olympic medal in the 20 km race walking event). Indeed, even with an ability as basic as breathing, it could be argued that practitioners of hatha yoga are experts, in that they have mastered breathing techniques unknown to most people. Finally, this definition can be applied to the two meanings of "expertise" we have highlighted earlier. The application is trivial with the *know-how* meaning: we can simply observe whether an expert does better than a non-expert. Does Lionel Messi dribble more successfully than a third-division player, or does an

[1]A super-expert might correspond to what is sometimes called a "genius".

experienced surgeon operate better than a newcomer? The application is more delicate, but still possible, with the *know-that* meaning. The difficulty is not in testing the amount of knowledge – simple questionnaires can do this – but in the fact that knowledge itself can be of variable quality. For example, we would doubt the scientific quality of the knowledge used by an astrologer, but not by a civil engineer. This issue will be dealt with at great length in Chapter 12.

1.4 Why Study Expertise?

The study of expertise is important for society in several ways. First, it sheds important light on learning and the acquisition of knowledge, which can be used to develop better methods of instruction and training. Given the pace at which technology advances in our society, this is a significant contribution. For example, research on physics and mathematics expertise, together with other studies, has led to the development of artificial tutoring systems in mathematics that perform better than human teachers (see Chapter 8).

Second, research on expertise can lead to better ways of coaching experts. The clearest illustration of this comes perhaps from sport and music. In athletics, world records are improved every year due to better training techniques, and the difference between current and previous achievements is sometimes stunning. The winners of Olympic medals in the marathon one century ago recorded times similar to today's amateur runners. In swimming, the seven world records that earned Mark Spitz as many gold medals at the Munich Olympic Games in 1972 would not have been sufficient for qualification for the semi-finals in the 2008 Beijing Olympic Games.

Third, research on human expertise can inform the development of artificial expert systems performing at high or even human-like levels, as we shall see in Chapter 14. Expert systems are much cheaper, do not tire and do not move to other jobs – considerable advantages from the point of view of industry. Thus, expert systems can make valuable contributions to the economy.

With respect to cognitive psychology, research on expertise has shed important light on human cognition, and several general cognitive mechanisms have first been identified in expertise research. These include the role of pattern recognition in decision making and problem solving, progressive deepening and selective search. (We will discuss these mechanisms in detail in Chapter 4.) Thus, just as neuropsychology illuminates human cognition by studying a "special" population characterised by brain damage, expertise research provides critical information on cognition by focusing on individuals who go beyond the limits that mar most of us. In both cases, looking at an atypical population offers a unique window on typical cognition.

Positive psychology, which is now a very influential approach in psychology, was created from the observation that most psychology devoted all its energy to negative aspects of human psychology, such as pathology, while ignoring its more positive aspects (Linley et al., 2006; Seligman & Csikszentmihalyi,

2000). By contrast, positive psychology focuses on hope, optimism and other human virtues. It might be worth emphasising that research on expertise, which focuses on humans' creativity and their potential to achieve extraordinary performances, had unequivocally anticipated at least some of the claims of positive psychology.

1.5 Preview of Book

The following chapters deal with the psychology of expertise. Chapter 2 focuses on perception and categorisation. It shows that *perception* lies at the heart of expertise: experts literally "see" things differently compared to novices, enabling them to categorise situations and problems better. Chapter 3 argues that this superior perception is due to the vast amount of *knowledge* that has been stored in *long-term memory* (LTM) during the years of practice necessary to reach expertise. Numerous theories have been developed to explain expert memory, and this chapter reviews the main candidates.

In Chapters 4 and 5, we shall see how these differences in perception and knowledge affect *problem solving* and *decision making*. They also affect experts' *intuition*, *insight* and *creativity*, topics of Chapter 6. In all cases, non-cognitive factors are involved as well. These include *personality* and *intelligence*, which are covered in Chapter 7. This chapter examines different approaches, mostly from differential psychology, that defend the role of *talent*, and it also addresses the issue of *gender differences*. In domains such as mathematics, science and chess, men vastly outperform women; is the origin of these differences social or biological? Finally, the chapter examines the hypothesis that creativity might benefit from *psychopathologies* such as manic depression and schizophrenia. When discussing these issues, these chapters provide an overview of the *key empirical results*, the *methods* used to obtain these results, and the *main theories* developed to explain them.

Chapter 8 covers the links between expertise, learning and education. It is concerned with four broad issues. First, it addresses the implications of theories based on talent for education. Second, it discusses the role of *practice* in acquiring expertise, and what theories focusing on practice tell us about the *training of experts*. If the theories presented in Chapters 2, 3 and 4 are correct, then it should be possible to isolate the components of *knowledge* that experts must acquire and design instruction and training methods that optimise their transmission to budding experts. Suitable practice schedules can then be designed and optimal feedback can be provided. In the extreme case, aspects of coaching could be automated with *intelligent tutoring systems*. Great attention will be devoted to the *deliberate practice* framework, which has been very influential in recent years. Proponents of *deliberate practice* argue that there is no empirical evidence for the role of talent in the development of expertise, and this claim will be discussed. The third issue addressed in this chapter is that of *transfer*. Do skills acquired in one domain transfer to others?

How do some experts appear to move to a different domain of expertise seamlessly, for example from being a biochemist to university vice-chancellor, while others fail to make such transitions? Finally, the chapter addresses the question of *expert learners* and *expert teachers*. Are some individuals just better than the majority at acquiring new information? Are some individuals particularly efficient at transmitting information to others? If so, what does this tell us about education in general?

Chapter 9 covers expertise across the life span. How does expertise develop with children? What are the respective roles of knowledge (including strategies) and biological maturation? What light do *savants* throw on expertise in general? Is the talent of *gifted children* limited to a single domain? At the other side of the life span, we will consider how *ageing* affects expertise, and whether expertise acts as a moderating variable in the ageing process. We will also consider how the careers of creative people evolve across time.

Chapter 10 addresses the links between expertise, biology and neuroscience. It discusses the influential theory proposed by Geschwind and Galaburda (1987), which ties together data from psychopathology (e.g. *dyslexia* and *autism*), developmental neuroscience and expertise in a large variety of domains including mathematics, visual arts and music. Recently, important discoveries have been made with the advent of novel *brain imaging techniques* (e.g. functional magnetic resonance imaging) as well as new developments with older techniques (e.g. electro-encephalography), and this chapter reviews the most important of them. These cover a large variety of expertise domains, most notably *sports* and *music*. The key notion of *brain plasticity*, which impinges on the interpretation of some of these data, is also examined. Finally, a better understanding of the biological mechanisms underpinning expertise raises the possibility of *creating new drugs* that will speed up the development of experts and enhance their performance. How far are we from this Brave New World?

Chapters 11 and 12 deal with expertise and its place in society. In some domains, the *distinction between experts and non-experts* is obvious. If one doubts that Maryam Mirzakhani, who in 2014 was the first woman, Muslim and Iranian to win the prestigious Fields Medal, is an expert in mathematics and more specifically the symmetry of curved surfaces, one can always try to identify errors in her proofs. However, as we have just seen, there are other domains – perhaps most domains in "real life" – where the definition of expertise is controversial. More generally, there is the issue that *expertise criteria* vary from one domain to the next, and that criteria are sometimes used inconsistently within the same domain of expertise. This particularly applies to *the professions*, which are the main kind of institutionalised expertise in industrialised countries (most notably lawyers and the medical profession).

How then are experts *selected* and *labelled* by society? Are official titles (such as those awarded by universities) always necessary? To what extent do *specific contexts* create new types of expertise and new experts? Is expertise just the product of an arbitrary selection from a particular group? What are the specific

practices that enable social and cultural authority? Do experts in Scientology and astrology have the same status as experts in neuroscience and astronomy? What is the *role of scientific knowledge* in validating experts? Are today's experts tomorrow's non-experts? These considerations are answered by results from sociology research.

Another key topic of these chapters concerns the *power of experts*, at least in industrialised societies. Directly or indirectly, experts played a role in the recent global financial crisis either by condoning financial practices that were – with the benefit of hindsight – too risky or failing to predict the consequences of these practices on the dynamics of markets. Similarly, experts have a considerable impact on *political decisions* (consider, for example, global warming or the 2009 swine flu pandemic), even though the science itself is a matter of dispute amongst experts. This raises complex questions about *experts' legitimacy and accountability.*

These chapters also address the extent to which it is possible to *communicate expert knowledge* – an issue that is crucial in legal settings, for example with expert testimony. Authors such as Luhmann (1995) have argued that experts essentially cannot communicate knowledge outside their constituency. This is because social communication systems each make sense of their environment using their own code. Others, such as Mieg (2001), have been more sanguine about experts' ability to do so. Finally, the chapters address the question as to how the *mass media* and more recently the *Internet* affect the way expert knowledge is communicated.

The final theme addressed in these chapters is the issue of the legal status of the expert. There are vast differences in the way experts are *defined and selected in different legal systems.* These chapters compare and contrast practices in the common law jurisdictions of Anglo–American courts with the civil law jurisdictions within continental Europe. Key questions include an analysis of current systems of *appointment of expert witnesses* and, more generally, of the designation of someone as an "expert". Another issue is that the legal coding of information will be different to that used, for example, in engineering. As a consequence, *expert opinion* will have a different meaning and significance within the legal system to those within the domain from which the expertise originated, often creating serious misunderstandings and distortions.

The discussion of the philosophy of expertise in Chapter 13 will allow us to revisit some of the central questions of this book: the question of *rationality*, the nature of *knowledge* acquired by experts (*knowing-that* and/or *knowing-how*), and the nature of *scientific knowledge.* Anticipating the following chapter, it will also address the *philosophical implications* of artificial systems emulating human experts.

A motivation for some of the research discussed in Chapters 2 and 3 was that a sound understanding of the cognitive processes underlying expert behaviour should make it possible to develop *artificial systems* that are able to perform as well as, or even better than, human experts. The field of *expert systems* is a recognised and active discipline of computer science, and there

are a number of expert systems developed to the point that they are crucial to some industries (for example, banking and geology). Chapter 14 discusses *strengths and weaknesses of such systems* as well as other related issues. What are the differences between expert systems and human experts? How is knowledge elicited from experts? Can experts really communicate their perceptual and procedural knowledge? What do expert systems teach us about *human expertise and human psychology* more generally?

Finally, the conclusion weaves together several of the strands that were discussed in previous chapters. It proposes a synthesis, highlighting the issues that should be addressed in future research.

1.6 Chapter Summary

This chapter started with a discussion of the two key meanings of expertise: knowing-that and knowing-how. It then considered a number of definitions of expertise, each emphasising a different aspect (e.g. type of measurement or place in society). It was noted that many of these definitions suffer from weaknesses. A fair amount of space was devoted to the question as to why we should study expertise. The main reasons were: the development of better methods for coaching and instruction in general, the prospect of building artificial-intelligence programs that can emulate human experts and to improve our understanding of human cognition.

1.7 Further Reading

Several edited books provide worthwhile overviews of the various ways expertise has been studied. Chi et al. (1988), Ericsson and Smith (1991b), Ericsson (1996b) and Staszewski (2013a) focus on cognitive psychology, although other viewpoints are occasionally discussed. Feltovich et al. (1997) discuss both human and machine expertise, with a special interest in the role of context. Ericsson et al.'s handbook (2006) provides a comprehensive overview of the psychology of expertise, with a strong emphasis on deliberate practice. Another handbook (Simonton, 2014) focuses on extreme forms of expertise – genius.

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