

Contents

<i>List of Illustrations</i>	<i>xiii</i>
<i>Preface</i>	<i>xv</i>
<i>Acknowledgements</i>	<i>xvii</i>
<i>Publisher’s Acknowledgements</i>	<i>xviii</i>
<i>List of Abbreviations and Acronyms</i>	<i>xx</i>
1 Introduction	1
1.1 Preview of Chapter	1
1.2 The Dual Meaning of the Term “Expertise”	1
1.3 Definitions of Expertise	2
1.4 Why Study Expertise?	6
1.5 Preview of Book	7
1.6 Chapter Summary	10
1.7 Further Reading	10
2 Perception and Categorisation	11
2.1 Preview of Chapter	11
2.2 De Groot’s Seminal Research	11
2.3 Medical Expertise	14
2.4 Holistic Perception and Anticipatory Schemata	16
2.5 Perception in Sport	17
2.6 Perception in Music	19
2.6.1 <i>Basic Skill Differences in Perception</i>	20
2.6.2 <i>Absolute Pitch</i>	21
2.6.3 <i>Laypeople’s Implicit Musical Expertise</i>	23
2.6.4 <i>Sight-Reading</i>	24
2.7 Perceptual Learning, Perceptual Expertise and Categorisation	27
2.8 Chapter Summary	28
2.9 Further Reading	28
3 Memory	29
3.1 Preview of Chapter	29
3.2 Chase and Simon’s Research	29
3.2.1 <i>The Key Empirical Results</i>	29
3.2.2 <i>Chunking Theory</i>	30
3.3 Generalisability of Experts’ Superiority in Recall Tasks	33
3.4 Is Knowledge Structured as Chunks?	33
3.5 How Many Chunks Are Stored in LTM?	36

3.6	Does Randomisation Eliminate Experts' Superiority?	37
3.7	Is STM Capacity Limited and Are LTM Encoding Times Slow?	39
3.8	The Intermediate Effect in Medicine	44
3.9	Memory in Sports	46
3.10	Memory in Music	47
3.11	Theoretical Accounts	48
	3.11.1 <i>Chase and Simon's Chunking Theory</i>	48
	3.11.2 <i>Skilled Memory Theory</i>	49
	3.11.3 <i>Long-Term Working Memory</i>	49
	3.11.4 <i>Revisions of Chunking Theory</i>	51
	3.11.5 <i>Constraint Attunement Theory</i>	58
3.12	Chapter Summary	60
3.13	Further Reading	60
4	Problem Solving	61
4.1	Preview of Chapter	61
4.2	De Groot's Research	62
4.3	Phases of Problem Solving	63
4.4	Expertise Effects in Progressive Deepening	64
4.5	Macrostructure of Search	66
4.6	Directionality of Search	67
4.7	Planning	67
4.8	Evaluation	68
4.9	The Role of Pattern Recognition in Problem Solving	69
4.10	The Role of Perception in Problem Solving	70
4.11	The Role of Schemata and Conceptual Knowledge in Problem Solving	70
4.12	The Role of Representations	73
	4.12.1 <i>Physics</i>	73
	4.12.2 <i>Economics</i>	74
4.13	Automatisation and Rigidity of Thought	75
	4.13.1 <i>Automatisation</i>	75
	4.13.2 <i>Rigidity of Thought</i>	76
4.14	Theories of Problem Solving	78
	4.14.1 <i>The Selz-de Groot Framework</i>	78
	4.14.2 <i>Newell and Simon's Problem-Space Theory</i>	78
	4.14.3 <i>Chunking Theory and Template Theory</i>	79
	4.14.4 <i>Holding's Theory</i>	80
	4.14.5 <i>Computer Models of Human Search</i>	80
4.15	Chapter Summary	84
4.16	Further Reading	84
5	Decision Making	85
5.1	Preview of Chapter	85
5.2	Rationality and Bounded Rationality	85
5.3	The Heuristics and Biases Approach	86

5.4	Biases in Experts	87
5.5	Fast and Frugal Heuristics	88
5.6	Naturalistic Decision Making	89
5.7	The SOS Effect	91
5.8	Shanteau's Framework	92
5.9	Decision Making in Sports	93
	5.9.1 <i>Using Task-Specific Probabilities</i>	93
	5.9.2 <i>Option Selection</i>	94
5.10	Chapter Summary	95
5.11	Further Reading	96
6	Intuition, Insight and Creativity	97
6.1	Preview of Chapter	97
6.2	Expert Intuition	97
	6.2.1 <i>Simon's Theory</i>	98
	6.2.2 <i>Dreyfus and Dreyfus's Theory</i>	99
	6.2.3 <i>Template Theory of Intuition</i>	100
	6.2.4 <i>Too Much of a Good Thing?</i>	100
6.3	Insight	101
6.4	Creativity	103
	6.4.1 <i>Are Estimations of Creativity Reliable?</i>	103
	6.4.2 <i>Tests of Creativity</i>	105
	6.4.3 <i>Factors Supporting the Development of Creativity</i>	106
	6.4.4 <i>Theories of Creativity</i>	108
6.5	Chapter Summary	113
6.6	Further Reading	114
7	Talent, Individual Differences and Gender Differences	115
7.1	Preview of Chapter	115
7.2	Talent Approaches Based on Intelligence	115
	7.2.1 <i>A Brief Overview of Early Intelligence Research</i>	115
	7.2.2 <i>Two Classic Studies on Intelligence and Talent</i>	117
	7.2.3 <i>Gardner's Approach</i>	118
	7.2.4 <i>IQ as Predictor of Expert Performance</i>	119
	7.2.5 <i>Components of Intelligence</i>	120
	7.2.6 <i>Intelligence: Discussion</i>	120
7.3	Talent Approaches Not Based on Intelligence	121
	7.3.1 <i>Talent in Chess</i>	121
	7.3.2 <i>Talent in Music</i>	123
	7.3.3 <i>Talent in Sports</i>	124
7.4	Personality	127
	7.4.1 <i>Creativity</i>	128
	7.4.2 <i>Other Domains of Expertise</i>	129
7.5	Psychopathology	129
7.6	Gender Differences	131
	7.6.1 <i>General Explanations</i>	132
	7.6.2 <i>Explanations Based on Intelligence</i>	134

7.7	Chapter Summary	137
7.8	Further Reading	137
8	Learning and Education	138
8.1	Preview of Chapter	138
8.2	Approaches Based on Talent	138
8.3	Approaches Based on Practice	139
8.3.1	<i>Identifying Strategies</i>	139
8.3.2	<i>Chunking Theory</i>	139
8.3.3	<i>Template Theory</i>	140
8.3.4	<i>ACT-R and Intelligent Tutoring Systems</i>	141
8.3.5	<i>Deliberate Practice</i>	142
8.3.6	<i>Discussion: Talent vs. Practice Revisited</i>	149
8.4	The Question of Transfer	150
8.4.1	<i>Differential Predictions of the Talent and Practice Approaches</i>	150
8.4.2	<i>Early Specialisation vs. Diversification in Sports</i>	151
8.5	Expert Teachers and Learners	153
8.5.1	<i>Expert Teachers</i>	153
8.5.2	<i>Expert Learners</i>	155
8.6	Chapter Summary	156
8.7	Further Reading	157
9	Development and Ageing	158
9.1	Preview of Chapter	158
9.2	Expertise and Development	158
9.2.1	<i>Domain-General Mechanisms</i>	158
9.2.2	<i>Domain-Specific Mechanisms</i>	159
9.2.3	<i>The Role of Strategies</i>	162
9.2.4	<i>Gifted Children</i>	162
9.2.5	<i>Savants</i>	163
9.3	Expertise and Ageing	164
9.3.1	<i>Effects of Age</i>	165
9.3.2	<i>A Paradox</i>	165
9.3.3	<i>Expertise as a Moderating Variable</i>	166
9.3.4	<i>Theories</i>	166
9.3.5	<i>The Careers of Great Creators as a Function of Age</i>	167
9.4	Chapter Summary	169
9.5	Further Reading	169
10	Neuro-Expertise	170
10.1	Preview of Chapter	170
10.2	Skill Acquisition in Novices	170
10.3	Typical Data in Neuro-Expertise	172
10.3.1	<i>Mental Calculation</i>	172
10.3.2	<i>Memory Champions</i>	172

10.3.3	<i>Chess</i>	173
10.3.4	<i>Music</i>	173
10.3.5	<i>Taxi Drivers</i>	174
10.3.6	<i>Sports</i>	174
10.4	Proposed Mechanisms	176
10.4.1	<i>The Fixed Localisation vs. Perceptual Expertise Debate</i>	176
10.4.2	<i>Mechanisms Linked to Intelligence</i>	178
10.4.3	<i>Functional Reorganisation of the Brain: The Role of Retrieval Structures and Templates</i>	180
10.4.4	<i>Geschwind and Galaburda's (1987) Theory</i>	180
10.5	Gender Differences	181
10.6	Smart Drugs	182
10.7	Chapter Summary	183
10.8	Further Reading	184
11	Experts and Society	185
11.1	Preview of Chapter	185
11.2	The Difficulty of Making Correct Predictions	185
11.3	A Miscarriage of Justice	186
11.4	When Experts Fail	187
11.4.1	<i>Difficulties with Scientific Research</i>	188
11.4.2	<i>Predictions in Political Science</i>	190
11.5	The Role of Media	193
11.6	Fraud and Cheating in Science	194
11.7	The Internet	196
11.8	Group Phenomena	197
11.9	Why Do We Believe Experts?	200
11.10	Situated Action	201
11.11	Chapter Summary	201
11.12	Further Reading	202
12	Sociology	203
12.1	Preview of Chapter	203
12.2	The Sociology of Professions	203
12.2.1	<i>Early Work</i>	203
12.2.2	<i>Abbott's Seminal Work</i>	205
12.2.3	<i>Experts as Heuristics</i>	206
12.3	Communication and Expertise	207
12.4	Experts in Court	208
12.5	Classification of Experts	210
12.5.1	<i>Mieg's Classification</i>	210
12.5.2	<i>Collins and Evans's (2007) Periodic Table of Expertises</i>	211
12.5.3	<i>Classifications of Expertise: Evaluation</i>	214
12.6	Chapter Summary	215
12.7	Further Reading	216

13	Philosophy	217
13.1	Preview of Chapter	217
13.2	Ancient Greek Philosophy	217
13.3	Knowing-How and Tacit Knowledge: Ryle and Polanyi	219
13.4	Disagreement between Experts	221
13.5	Identification of Experts	222
13.6	Dreyfus's Critique of Expert Systems	224
13.7	Rationality and Expertise	225
13.8	Philosophy and Expertise: Applications	226
13.9	Chapter Summary	228
13.10	Further Reading	229
14	Artificial Intelligence and Expert Systems	230
14.1	Preview of Chapter	230
14.2	Knowledge Representation	230
14.3	Expert Systems	231
14.4	Knowledge Elicitation Techniques	233
14.5	Decline of Expert Systems Research	234
14.6	Contributions of Expert Systems Research	235
14.7	Chapter Summary	236
14.8	Further Reading	236
15	Putting It All Together	237
15.1	Preview of Chapter	237
15.2	Good and Bad News	237
15.3	Transversal Themes	238
	15.3.1 <i>Definition and Identification</i>	239
	15.3.2 <i>Rationality</i>	239
	15.3.3 <i>Knowledge</i>	241
	15.3.4 <i>Search</i>	241
	15.3.5 <i>Generativity</i>	242
	15.3.6 <i>Diachronicity</i>	243
	15.3.7 <i>Nature vs. Nurture</i>	243
	15.3.8 <i>Environment and Society</i>	243
15.4	Methods and Theories	244
15.5	Four Tensions (Almost) Resolved	245
15.6	Practical Implications	246
15.7	How to Become an Expert	248
	15.7.1 <i>Performance-based Expertise</i>	248
	15.7.2 <i>Reputation-based Expertise</i>	249
15.8	Conclusion: Toward an Integration of Research on Expertise?	249
15.9	Chapter Summary	251
15.10	Further Reading	251
	<i>References</i>	252
	<i>Index</i>	293

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 deliberately 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

¹A 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.

Index

In this index *f* represents figure and *t* represents table.

A

AARON (computer program), 111–112
 Abbott, A., 205–206, 214
 Abnormalities, 91
 Absolute pitch (AP), 21–23
 Academic appointments, gender differences and, 131–132
 Action, chunking and, 32, 140
 ACT-R (Adaptive Control of Thought) tutor, 141–142
 Adaptive expertise, 242
 Adequacy criterion, 85
 Advanced beginner stage, of intuition expertise, 99
 Affordances, 201
Against Method (Freyerabend), 220
 Age
 intelligence and, 116
 memory and, 159–160
 strategies, memory and, 162
 Ageing, expertise and
 careers of great creators as function of, 167–169
 deliberate practice and, 166–167
 effects of, cognition and, 165
 moderating variable, expertise and, 166
 paradox, 165
 theories of, 166–167
 AI. *See* Artificial intelligence
Alchemy and Artificial Intelligence (Dreyfus), 224
 American functionalism, 204
 Anticipation tasks, 176
 Anticipatory schemata, 16–17
 Anti-intellectualism, 219
 Applied philosophy, 226
 Arational thought, 225, 226
 Architectonic ear, 123
 Aristotle, 218
 Articulatory loop, 52
 Artificial intelligence, creativity and, 111–112

Artificial intelligence (AI)
 Dreyfus's critique of, 224
 expert system research, contributions, 235–236
 expert systems and, 231–232
 knowledge and, 241
 knowledge elicitation techniques, 233–234
 knowledge representation, 230–231
 psychology, knowledge representations and, 232
 research, decline of, in expert systems, 234–235
 search and, 241–242
 Asperger's, 134
 Assumption of monotonicity, 146, 148
 Assumption of rationality, 239–240
 Atonal music, 22
 Attributions, gender and, 133
 Automatisation, problem-solving and, 75–76
 Autonomous phase, behaviour and, 75–76

B

Backward search, 67
 Base rate neglect, 87
 Beer-mat knowledge, 212
 Behaviours, in/out group, 199
 Being-in-the-world, 224
 Biases
 confirmation, 200
 decision making and, 87–88
 egocentric epistemic, 222
 gender and, 133
 publication, 189
 Binet, Alfred, 115–116
 Binet-Simon test, 116
 Biological age, 116
 Biological markers, for talent/intelligence, 122
 Biological mechanisms, of neuro-expertise, 178–180
 Biomedical knowledge, 45
 Bipolar disorder, 130
 Birth order effect, intelligence and, 106
 Bodily-kinaesthetic intelligence, 118
Bounce (Syed), 143

- Bounded rationality, decision making and, xvi, 85–86, 114, 240–241
- Brain imaging
chess and, 173
episodic memory and, 172
functional reorganisation of, retrieval structures, templates and, 180
fusiform face area and, 177
intelligence, gender, head size and, 178–180
intelligence, gender differences and, 181–182
knowledge acquisition and, 174
memory experts and, 172–173
skill acquisition in novices, 170–172
smart drugs and, 182–183
sports, neuro-expertise and, 174–176
visuospatial function and, 180–181
- Brain imaging techniques, 171
- Brain plasticity, 175, 180, 182
- Brainstorming, 199
- British Journal of Psychology*, 57
- Brute force, 235
- Bureaucracies, 204
- C**
- Calibration measures, 191
- CaMeRa computation model (Tabachnek-Schijf), 75
- Career age, 167
- Careers, ageing and, 167–169
- Carlsen, Magnus, 148
- Cartesian dualism, 219
- Categorisation, 27–28
- Charmides* (Plato), 222
- Chase, W. G., 29–33, 79–80
- Chassy, P., 100
- Cheating
in science, fraud and, 194–195
in sports, 195–196
- Check configurations, 173
- Chess
age, memory and, 160
blindfolded playing, 141
gender and, 133–134
intelligence and, 120
memory, 29–39
neuro-expertise and, 173
perception, 11–14
problem solving, 62–73
and reliable measure of expertise, 144
talent and, 121–123
- Chi, M. H., 160
- CHREST simulation program, 16, 36, 37–38, 244, 250
- evaluation of, 56–58
template theory, chunking and, 52–56
- CHUMP, computer simulation program, 82–84
- Chunking theory (Chase & Simon), 30–33, 48–60
age and, 165
ageing model and, 166
digit span test and, 161
EPAM-IV and, 52
expert's superiority, recall tasks and, 33
knowledge structured as, 33–36
long-term memory storage and, 36–37
practice, talent identification and, 139–140
problem-solving and, 79–80
random positions and, 39
revisions of, 51
template theory, CHREST and, 52–56
- Chunks, memory and, 30
- Circumferential scan pattern, 15
- Classification, of expert roles, 210–211
evaluation, 214–215
periodic table of expertises, 211–214
- Clinical knowledge, 45
- Clinical vs. Statistical Prediction* (Meehl), 90
- Closure, professions and, 204
- Coding
location, 37
LTM and, 41
musical stimuli, 25
- Cognition, 4
deceptive moves and, 176
decision making and, 88–89
domain general mechanisms and, 158–159
situated action and, 201
smart drugs and, 182–183
- Cognitive biases, 88
- Cognitive liberty, 183
- Cognitive phase, behaviour and, 75–76
- Cohen, Harold, 111–112
- Collaboration, research and, 197–200
- Collins, M. H., 211–214
- Collins and Evan's periodic table of expertises, 211–214
- Common law, 208
- Communication, stories and, 200
- Compensatory mechanisms, age and, 165
- Competence stage, of intuition expertise, 99
- Computer simulations, 58

- Concept formation, 27–28
 Concept learning, 27–28
Concept of Mind, The (Ryle), 219
 Conceptual knowledge, problem-solving and, 70–71
 Condition, chunking and, 32, 140
 Confirmation bias, 200
 Conflict resolution rules, 82
 Connectionist models, computer simulation program, 81–82
 Connoisseurship, 97
 Conscientiousness, 129
 Constraint attunement theory, 58–60
 Contributory expertise, 211*t*, 213
 Control, professions and, 204
 Control condition, 47
 Copy task, 30
 Core
 encoding and, 232
 templates and, 54
 Core mirror neuron system, 176
 Corticomotor system, 174
 Cost-benefit analysis, 86
 Court, experts in, 208–209
Creating Minds (Gardner), 118
 Creating thinking, tests of, 105
 Creativity
 artificial intelligence and, 111–112
 intelligence and, 119
 mental health and, 130
 personality and, 128–129
 stages of, 108
 tacit knowledge/knowing, 219–220
 Creativity, expert, 103–113
 education/training, development of and, 106–107
 estimations of, reliability, 103–104
 family environment/socioeconomic conditions, development of and, 106
 sociocultural contexts, development of and, 107–108
 tests of, 105–106
 Creativity, theories of
 as product of unconscious mechanisms, 108–109
 as search through problem space, 109–110
 selection mechanisms and, 110–113
 Creativity test, 76–77
 Credentials, 211*t*, 214, 222–223
 Csikszentmihalyi's phenomenon of flow, 146
- D**
 Darwinian mechanisms of variation and selection, 110
 Data, fraud/cheating, science and, 194–195
 Data mining, 235
 Deception identification, 176
 Decision experts, 211
 Decision making
 biases approach to, 87–88
 fast/frugal heuristics, 88–89
 group phenomena, experts and, 197–200
 heuristics approach to, 86–87
 intuition and, 97–98
 naturalistic, 89–91
 rationality/bounded rationality, 85–86, 239–241
 satisfaction of search effect and, 91
 Shanteau's framework for, 92
 in sports, 93–95. *See also* Sports, decision making in
 Declarative memory, 182–183
 Defining expertise, 2–6, 239
 de Groot, Adriaan, 11–14, 62–63, 78
 Deliberate play, 152
 Deliberate practice, 142–149
 ageing and, 166–167
 assumption of monotonicity, 146, 148
 data supporting, 143–144
 evidence against, 144–149
 herding and, 199–200
 individual vs. team, 146–147
 lack of enjoyment, 146
 logical/methodological issues, 147–148
 other interests, training in, 147
 talent vs. practice, 149
 theory of, 142–143
 violation of 10-year, 10,000-hour rules, 146
 DENDRAL expert system, AI and, 231–233, 242
 Detection tasks, 19
 Deutsch's scale illusion, 21
 Development, expertise and diachronicity and, 243
 domain-general mechanisms, 158–159
 domain-specific mechanisms, 159–161
 of expert systems, 236
 gifted children, 162–163
 savants and, 163–164
 Diachronicity, expertise and, 243

- Differential predictions of talent/
practice, 150–151
- Digital Equipment Corporation (DEC),
232–233
- Digit span test, 40, 53, 57, 161
- Direction identification, 176
- Disagreement, between experts,
221–222
- Discipline integration, expertise and, 250
- Discrimination, expertise and,
213–214
- Discrimination measures, 191
- Discrimination network, 31, 32*f*, 53*f*
- Dispositions, 211*t*, 212, 219
- Divergent production tests, 105
- Divergent semantic units, 105
- Diversification, specialisation in sports
and, 151–152
- Domain general mechanisms,
development and, 158–159
- Domain selection, 249
- Domain-specific mechanisms,
development and, 159–161
- Doping, sports cheating and, 195–196
- Downward discrimination, 214
- Dreyfus, H. L., 99–100, 224–225
- Dreyfus, S. E., 99–100
- Dreyfus & Dreyfus theory of expert
intuition, 99–100
- Dreyfus & Dreyfus theory of expertise,
225, 226, 244
- Drugs
smart, neuro-function and, 182–183
sports, cheating and, 195–196
- DSM-III (Diagnostic and Statistical
Manual of Mental Disorders), 130
- Dualism, 219
- Dual theories, of intuitive expertise,
100–101
- Durkheim, Emile, 204
- E**
- Economic null hypothesis, prediction
failure and, 187
- Economic representations, problem-
solving and, 74–75
- Economics, rationality and, 240
- Economy, professions and, 204
- Economy and Society* (Weber), 203–204
- Education
creativity development and, 106–107.
See also Learning
environment, society and, 243–244
generativity and, 242
knowledge and, 241
nature vs. nurture, 243
rationality and, 241
smart drugs and, 182–183
- Egocentric epistemic bias, 222
- Ego strength, 130
- Ehrlich Paul, 187–188
- Einstellung effect, 77, 88
- Electroencephalography (EEG), 171,
179
- Elo, A., 122, 167
- Elo rating, 3–4, 72, 121
- Emotional responses, 154
- Empathizing-systemizing theory, 134
- Empirical data, chunking theory and,
48
- Energy, personality and, 128
- Environment
expertise, society and, 243–244
gifted children and, 162–163
- EPAM-IV, memory theory and, 52,
56–58
- Episteme* (Aristotle), 218
- Epistemic peer disagreement, 221–222,
223
- Epistemic peers, 221–222
- Epstein, D., 3
- Equal-eight view, 222
- Ericsson, K. A., 49–51, 143
- Errors, in scientific research/publication,
189–190
- Ethical issues, expertise and, 247
- Evaluation
of expert classification, 214–215
problem-solving and, 68–69
- Evans, R., 211–214, 225–226
- Event-related potentials (ERP), 171
- Existential intelligence, 118
- Expansive mode, 228
- Expected utility theory, 86
- Experience, 211*t*, 214
- Expert analysts, 210
- Expert creativity, 103–113. *See also*
Creativity, expert
- Expert insight, 101–102
- Expert intuition. *See* Intuition, expert
- Expertise
communication and, 207–208
defining/identification and,
2–6, 239
diachronicity and, 243
dual meaning of, 1–6
ethical issues, 247
failure of, 91

- five-stage model of (Dreyfus & Dreyfus), 225
- four tensions, 245–246
- generativity and, 242
- interactional, 208
- knowledge and, 241
- medical, 14–16
- methods/theories, 244–245
- nature *v.* nurture, 243
- perceptual superiority and, 17–18
- performance-based, 248–249
- performance/reputation-based, 239
- periodic table of, 211–214
- philosophy, applications of and, 226–228
- positive/negative aspects, 237–238
- practical implications, 246–248
- rationality and, 225–226, 239–241
- reputation-based, 249
- search and, 241–242
- specialisation effects in, 72–73
- transversal themes of, 238–239
- why study?, 6–7
- Expertise reversal effect, 154
- Expertise stage, of expert intuition, 99
- Expert knowledge, 250
- Expert learners, 155–156
- Expert Mirror Neuron System, 176
- Expert-novice comparisons, 154
- Expertocracy, society and, 193
- Expert patients, 197
- Expert performance, IQ as predictor of, 119–120
- Expert researchers, 210
- Expert roles, 210–211
- Expert(s)
 - becoming an, 248–249
 - biases in, 87–88
 - in court, 208–209
 - disagreements between, 221–222
 - failure of, 187–188
 - identification of, 222–224, 248
 - society and. *See* Society, experts and super, 250–251
 - why do we believe, 200–201
- Experts, classification of
 - Collins and Evans's periodic table of expertises, 211–214
 - Mieg's, role classification, 210–211
- Expert systems, 209
 - AI and, 231–233
 - Dreyfus critique of, 224–225
 - knowledge elicitation techniques, 233–234
 - research, contribution of, 235–236
 - research, decline of, 234–235
- Expert teachers, 153–155
- Exposure time, 46
- Expressive ear, 123
- External expertise, 211*t*, 213
- External problem space, 78–79
- Extra-weight view, 222
- Extroversion, 128, 129
- Eye-hand span, 26
- Eye movement patterns, 14–16, 24, 56, 70, 78, 82
- Eye-voice span, 26
- F**
- Facial recognition, 176–177
- Factor analysis, 116
- Fads, prediction, experts and, 188
- Failure, of experts, 187–188
 - political science, predictions in, 190–192
 - scientific research and, 188–190
- Fake experts, 222–223
- Family conditions, creativity
 - development and, 106
- Fast and frugal heuristics, 88–89
- Fast Company*, 143
- Fear of success, 133
- File-drawer problem, 190
- Final phase, of problem-solving, 64
- First-person subjective experience, 224
- First phase problem-solving, 63–64
- Five-stage model of expertise (Dreyfus & Dreyfus), 225
- Fixation of abnormality, 15
- Fixed localisation vs. perceptual expertise, 176–178
- Flexibility, teaching and, 154
- Flow (Csikszentmihalyi's theory of), 128, 146
- Formal experts, 211
- Formalisms, 231
- Forward search, 67
- Four tensions, talent vs. practice, 245–246
- Frame, 232
- Frames of Mind* (Gardner), 118
- Framing effect, 87
- Framing phase, of problem-solving, 64
- Fraud
 - fake experts, 222–223
 - in science, 194–195
- Functional Magnetic Resonance Imaging (fMRI), 171, 177

Functional reorganisation, 174, 180
 Fusiform face area, 177
Future of Management, The (Hamel & Breen), 188

G

Galton, Francis, 115
 Gardner, Howard, 118
 Gardner's approach, to intelligence and talent, 118
 Gaze-contingent window paradigm, 13–14, 15
 Gender differences
 Asperger's, 134
 brain functions and, 178
 empathizing-systemizing theory, 134
 females, verbal IQ/speed tasks and, 135–136
 gaps, in sciences/arts and, 131–136
 intelligence and, 134–136, 181–182
 in mathematics, 132
 in sports performance, 124
 statistical explanations, 132–134
 in talent, 117, 119
 testosterone exposure in utero, 180
 Gene-constellation hypothesis, intelligence and, 120–121
 General Intelligence, 134
 Generalisability of skills, 150–152
General Problem Solver (Newell & Simon), 224
 General theories, 103
 Generation of solutions, creativity and, 109–110
 Generativity, expertise and, 242
 Generic description, 50–51
 Genetic markers, sports and, 124–126
 Genetics of talent, 149
Genius in All of Us, The (Shenk), 143
 Geschwind and Galaburda's theory of talent, 122, 180–181
 Gestalt psychology, 16
 Gifted children, development and, 162–163
 Gilmartin, K., 36
 Glass ceiling, 133
 Global-focal search model, 15
 Goal-directed activities, 142, 151
 Gobet, F., 33–36, 100
 Greek philosophy, 217–218
 Group phenomena, experts, decision making and, 197–200
 Groupthink, 199
 Guilford's theory of intelligence, 105

H

Halo effect, media and, 193
 Handedness
 of chess players, 122
 talent, visuospatial domains and, 180–181
 Head size, intelligence and, 179
 Herding effect, 199–200
Hereditary Genius (Galton), 115
 Heredity, intelligence and, 120–121
 Heritability
 personality, talent and, 127–128
 sports and, 124–125
 Heterarchy, 232
 Heuristic approach, to decision making, 86–87
 Heuristics
 artificial intelligence and, 111–112
 decision making and, 88–89
 expert insight and, 102
 experts as, 206–207
 Hierarchical clustering, 234
 Hierarchical organisations, 204
 Hierarchies, 232
 Hindsight bias, 87
 Holding's theory, problem-solving and, 80
 Holistic perception, 16–17
 Holistic understanding, 226–227
 Homing heuristic, 66
 Horizontal décalages (Piaget), 159
 Human rationality, tests of, 89
 Human search, computer models of, 80–84
 CHUMP/SEARCH, 82–84
 connectionist models, 81–82
 NSS, MATER and, 80–81
 PERCEIVER, 81

I

Identical elements, theory of (Thorndike and Woodworth), 151
 Identifying expertise, 239
 Idiographic approach, 103
 IF-THEN rules, 232
 Illumination stage, of creativity, 108
 Illusion of control, 200
 Immediate reinvestigation, 64–66
 Implicit knowledge, 234
 Implicit learning, 234
 Implicit memory, 234
 Incubation stage, of creativity, 108, 109
 Individual differences, in talent, 117

- Inert knowledge, 142
 Inflexibility (rigidity of thought), 76–78
 Information, knowledge and, 197
 Information processing, intelligence and, 178
 Information theory, 59
 In-group behaviors, 199
 Insight, expert, 101–102
 Intellectualism, 219
 Intelligence, talent and, 115–121
 biological mechanisms linked to, 178–180
 components of, 120
 Gardner's approach (5 intelligences), 118
 gender differences and, 134–136, 181–182
 gene-constellation hypothesis, 120–121
 IQ as predictor of expert performance, 119–120
 performance and, 129
 Intelligent tutoring, 141–142
 Interactional expertise, 208, 211*t*, 212–213
 Interfering task, 25, 39–40
 Inter-individual variability, deliberate practice and, 145
 Intermediate effect, in medicine, 44–46
 Internal expertise, 211*t*, 213
 Internal meta-expertises, 211*t*, 213
 Internal problem space, 78–79
 Internet, society, expertise and, 196–197
 Interpersonal intelligence, 118
 Inter-piece latencies, 31
 Inter-rater correlation, 117
 Intersection positions, 55
 Intuition, expert, 97–101
 Dreyfus & Dreyfus, 99–100
 dual theories, 100–101
 in nursing, 226
 Simon's theory and, 98–99
 template theory of, 100
 Inverted U-curve, 44
 Invulnerability, 199
 IQ (intelligence quotient), 90, 116
 birth order effect and, 106
 chess and, 120
 gender differences and, 132–133
 as predictor of expert performance, 119–120
 savants and, 164
- J**
 Jurisdiction, professions and, 205
 Justice, miscarriage of, expertise and, 186–187
- K**
 KEKADA production system, 112
 Kinematic cues, 175
 Kintsch, W., 49–51
 Knowing how, 227
 Knowing how, philosophy and, 219–220
Knowing How and Knowing That (Ryle), 219
 Knowing that, 227
 Knowledge
 acquisition of, 141, 174
 assessment of, 227–228
 cognitive development and, 159
 communication and, 207–208
 compensatory mechanisms, age and, 165
 conceptual, problem-solving and, 70–71
 elicitation techniques, expert systems, AI and, 233–234
 expertise and, 241
 expertise classification and, 212–213
 information and, 197
 metacognitive skills and, 159
 organisation, schemas and, 42–43
 procedural, 234
 professions and, 205
 search and, 241–242
 stereotypical thinking and, 107
 testability of, 220
 ubiquitous tacit, 215
 Knowledge, chunks and, 33–36
 Knowledge representation
 AI and, 230–231
 psychology and, 232
- L**
 Labour division, 204
 Language learning, 56
 Large complexes, 70–71
 Latencies, 35
 Laypeople, musical expertise and, 23
 Learners, expert, 155–156
 Learning
 expert learners, 155–156
 expert teachers, 153–155
 machine, 235
 practice, based on, 139–149. *See also* Practice, talent and talent, based on, 138–139
 transfer and, 150–152

- Learning by example, 140
 Linear performance, 44
 Linguistic experience, 214
 Linguistic fluency, 212
 Linguistic intelligence, 118
 Local discrimination, 211*t*, 213
 Location coding, 37, 48
 Logic, formalisms and, 231
 Logical-mathematical intelligence, 118
Logic of Scientific Discovery (Popper), 220
 Long-term memory (LTM)
 chunks and, 31, 32, 33
 chunk storage and, 36–37
 schemas and organisation of knowledge, 42–43
 slow encoding times, 39–43
 template theory, CHREST and, 52–56
 See also Memory *entries*
 Long-term working memory (LTWM), 49–51
 Loose hierarchy, 232
 Lose-shift hypothesis, 66
 LTM. *See* Long-term memory
 LTWM. *See* Long-term working memory
 Lum, G., 227–228
- M**
- Machine learning, 235
 Macrostructure, of search, 66–67
 Macysma program, expert system, 234
 Mad genius theory, 130
 Management science, prediction failure and, 188
 MATER, computer simulation program, 80–81
 Mathematics, gender differences in, 132, 133–134
Matthew effect, 247
 Maximisation, 85
 McDowell's theory of rationality, 225–226
 Media, expertise and, 193
 Medical expertise, 14–16, 44–46
 Medical research, expert failure and, 188–190
 Mednick's theory of creativity, 105
 Meehl, P. E., 90
 Memory
 age and, 159–160, 165
 Chase & Simon's Chunking Theory, 29–33
 chunking theory, 30–33
 creativity and, 109
 digit span test and, 161
 domain-specific, decline in, 166
 episodic, brain function and, 172
 experts, brain function and, 172–173
 functional reorganisation of brain and, 180
 intermediate effect, in medicine, 44–46
 in music, 47
 randomisation and, 37–39
 savants and, 163–164
 smart drugs and, 182–183
 in sport, 46–47
 STM capacity, LTM encoding times and, 39–43
 task expertise and, 180
 Memory, theories of, 48–60
 constraint attunement theory, 58–60
 EPAM-IV, 52
 long-term working memory, 49–51
 revisions of chunking theory, 51
 skilled memory theory, 49
 Mental age, 116
 Mental calculations, brain function and, 172
 Mental energy, 178
 Mental health issues, talent and, 129–130
 Mental imagery, 32, 55–56
 Meritocracy, 193
 Merton, R. K., 247
 Metacognitive skills, 159
 Meta-criteria, 211*t*, 214
 Meta-DENDRAL, expert system, AI and, 232
 Meta-expertises, 211*t*, 213
 Method of loci, 40, 49
 Methodology, deliberate practice and, 147–148
 Mieg, H. A., 206–207, 209, 210–211, 214
Mind over Machine (Dreyfus), 225
 Mind-set effect, 77
 Mind's eye, problem-solving and, 32, 53*f*
 Mirror-neuron system, 176
 Mnemonics, 39–40
 Monotonicity, assumption of, 146
 Moral authority, 204
 Motivation, personality, creativity and, 128, 163
 Motor behaviour, 75–76

- Motor-evoked-potential amplitudes, 174
- Motor skills, neuro-expertise, sports and, 174–176
- Multidimensional scaling, 234
- Music
 intelligence and, 120
 memory in, 47
 neuro-expertise and, 173–174
 talent in, 123
- Music, perception in, 19–27
 absolute pitch, 21–23
 eye-hand span, 26
 eye movements, 24
 laypeople, implicit musical expertise, 23
 proofreader's area, 26–27
 short presentations, 24–25
 sight-reading, 24
- Musical ear, 123
- Musical intelligence, 118
- MYCIN, expert system, AI and, 231–232, 234
- N**
- Naturalistic decision making, 89–91
- Naturalistic intelligence, 118
- Nature vs. nurture, expertise and, 243, 250
- Neural network simulations, 167, 182–183
- Neuro-expertise
 chess and, 173
 environment, society and, 243–244
 fixed localisation vs. perceptual expertise, 176–178
 functional reorganisation of brain and, 180
 gender differences and, 181–182
 Geschwind and Galaburda's theory, 180–181
 intelligence, biological mechanisms and, 178–180
 memory experts and, 172–173
 mental calculations, data, 172
 music and, 173–174
 nature vs. nurture, 243
 skill acquisition, in novices and, 170–172
 sports and, 174–176
 taxi drivers, knowledge and, 174
- Neuroticism, 128, 129
- Newell and Simon's problem-space theory, 78–79, 112
- Nicomachean Ethics* (Aristotle), 218
- Node, 53, 62*f*, 231
- Nomothetic theories, 103
- Non-immediate reinvestigation, 64–66
- Nootropic drugs, education, brain function and, 182–183
- Novice stage, of intuition expertise, 99
- NSS, computer simulation program, 80–81
- O**
- Object discrimination, 176–177
- Object recognition, 177
- Ontology, 235–236
- Optimism, 192
- Option selection, sports, decision making and, 94–95
- Ordinary savants, 163
- Orientation zone, 70
- Outliers* (Gladwell), 143
- Output quantity, creativity and, 112
- P**
- Pain sensitivity, sports performance and, 125–126
- Parafoveal information, 15
- Partitioning technique, 35
- Pattern recognition
 expert intuition and, 98
 insight and, 102
 problem-solving and, 69–70
 search and, 82
 theory of search, 83*f*
- Peak, of career, ageing and, 167–168
- Pearson, Karl, 116
- Peers, disagreement between experts, 221–222
- PERCEIVER, computer simulation program, 81
- Perception
 de Groot research on, 11–14
 in music, 19–27. *See also* Music, perception in
 problem-solving role, 70
 in sports, 17–19
- Perceptual behaviour, 75–76
- Perceptual cue, 201
- Perceptual expertise, 27–28, 177–178
- Perceptual expertise vs. fixed localisation, 176–178
- Perceptual learning, 27–28
- Perceptual resources, 91
- Perfectionism, 129

- Performance
 of experts, failure and, 188
 rationality and, 240
 recall, age and, 165
 rehearsal and, 162
- Performance-based expertise, 239, 248–249
- Periodic table of expertise, 211–214
- Peripheral information, 15
- Personality, talent and, 127–129
 creativity and, 128–129
 need for achievement, 129
- Personal Knowledge* (Polanyi), 219–220
- Pessimism, 192
- Phenomenology, 224
- Philosopher kings, 218
- Philosophy
 ancient Greek, 217–218
 disagreements, between experts and, 221–222
 Dreyfus's critique, of expert systems and, 224–225
 environment, society and, 243–244
 expertise, applications of, 226–228
 identification, of experts, 222–224
 knowing-how, tacit knowledge and, 219–220
 rationality, expertise and, 225–226
 of science, expertise and, 220–221
- Phronesis (prudence), 218
- Physical Review Letters*, 190
- Physics, representations, problem-solving and, 73–74
- Piaget's theory of development, 158–159, 162
- Planning, problem-solving and, 67–68
- Plato, 217–218
- Platykurtic, 132
- Poincaré, Henri, 108
- Polanyi, Michael, 219–220
- Political anarchy, creativity and, 108
- Political science, predictions in, 190–192
- Politics as a Vocation* (Weber), 204
- Popular understanding, 212
- Population, famine and, prediction failure, 187–188
- Population Bomb, The* (Ehrlich), 187–188
- Positron emission tomography (PET) scans, 171
- Practice
 professions and, 205–206
 talent vs., 245–246
- Practice, talent and, 123
 ACT-R, intelligent tutoring and, 141–142
 chunking theory and, 139–140
 deliberate practice, 142–149. *See also* Deliberate practice
 differential predictions, transfer and, 150–151
 identifying strategies, 139
 music, neuro-expertise and, 173–174
 template theory, 140–141
- Predictions, expertise and, 185–186
 failure of experts, 187–188
 media and, 193
 in political science, 190–192
- Preparation stage, of creativity, 108
- Prescriptive mode, 227–228
- Presentation time, age and, 165, 166–167
- Primary source knowledge, 211*t*, 212
- Problem-solving
 conceptual knowledge and, 70–71
 de Groot's research and, 62–63
 directionality of search, 67
 evaluation and, 68–69
 expert systems and, 233
 macrostructure of search, 66–67
 mind's eye and, 32
 pattern recognition, role in, 69–70
 perception role in, 70
 phases of, 63–64
 planning and, 67–68
 progressive deepening, expertise effects and, 64–66
 representations role in, 73–75. *See also* Representations, problem-solving and
- Problem-solving theories
 chunking/template, 79–80
 computer models of human search, 80–84. *See also* Human search, human search
 Holding's theory, 80
 Newell and Simon's problem-space theory, 78–79
 Selz-deGroot Framework, 78
- Problem space theory (Newell & Simon), 78–79, 109–110
- Prodigious savants, 163
- Productions (rules of the type), 32, 140, 167, 232
- Productive thinking, framework, 78

- Product theories, 58–60
- Professions, sociology of
 Abbot's studies of, 205–206
 characteristics of, 203–205
 communication and, 207–208
 early works on, 203–205
 heuristics, experts as, 206–207
 role classification and, 211
 trust and, 209
- Proficiency stage, of intuition expertise, 99
- Progressive deepening, 63
 expertise effects in, 64–66
 problem-solving and, 64
- Proofreader's error, 26–27
- Protocol analysis, 233
- Psychology
 of intelligence, 115, 116
 knowledge and, 241
 knowledge representations and, 232
 nature vs. nurture, 243
- Psychometric tests, 105
- Psychopathological mechanisms, 134
- Psychopathy, talent and, 129–131
- Psychoticism, 128
- Publication bias, scientific research and, 189–190
- R**
- Raab, M., 94–95
- Rage to master, 163
- Randomisation, expert superiority and, 37–39
- Rationalisation, 199
- Rationality
 decision making and, 85–86, 89–91
 expertise and, 225–226, 239–241
- Rational organisations, 204
- Reaction times, age and, 165
- Reading music, 24
- Reasoning, age-related decline in, 166
- Recall task, 29–30, 33
- Referred expertise, 211*t*, 214
- Rehearsal strategy, 162
- Reingold, E. M., 12–14
- Relative experts, 210
- Relative pitch, 22
- Reliability, of creativity estimations, 103–104
- Remote Associates Test (RAT) of
 creativity, 76–77
- Replication, expert failure and, 188, 189–190
- Representations
 knowledge, AI and, 230–231
 language, 235
 situated action and, 201
- Representations, problem-solving and, 73–75
 automatism/rigidity of thought, 75–78
 economics, 74–75
 physics, 73–74
- Republic, The* (Plato), 217–218
- Reputation-based expertise, 239, 249
- Research, scientific
 contribution of expert system, 235–236
 on expertise, 248
 further, expertise and, 250
 groups and, 198
- Research scientific
 expert failure and, 188–190
- Retraction, scientific literature and, 190
- Retrieval cues, 173
- Retrieval structures, 39–40, 42*f*, 48, 49
 EPAM-IV and, 52
 functional reorganisation of brain and, 180
 LTWM and, 49–51
- Right-reasons view, 222
- Rigidity of thought, problem-solving and, 75, 76–78
- Role models, creativity and, 106–107
- Rorschach test, 90, 105
- Routine expertise, 242
- Ryle, Gilbert, 219–220
- S**
- Satisfaction of search effect, 91
- Satisficing, 85
- Satisficing mechanism, 80
- Savants, development and, 163–164
- Savoir comment faire, 227
- Savoir faire, 227
- Schemas
 knowledge organisation and, 42–43
 knowledge representations, psychology and, 232
 problem-solving role, 70–71
- Schizophrenia, 130
- Scholastic Aptitude Test for
 Mathematics, 132
- Science, fraud/cheating, experts and, 194–195

- Science as a Vocation* (Weber), 204
 Science philosophy, expertise and, 220–221
 Scientific literature, publication bias and, 189–190
 Script formation, 45
 Scripts, 232
 Search
 brute, 235
 computer models of human, 80–84.
 See also Human search, computer models of
 directionality of, 67
 expertise and, 241–242
 macrostructure of, 66–67
 through problem space, creativity and, 109–110
 SEARCH, computer simulation program, 82–84
Search for Excellence (Peters & Waterman), 188
 Search tree, 62–63
 Season of birth, talent/intelligence and, 122
 Selection mechanisms, creativity and, 110–113
 Self-regulation, 155, 156
 Selz, Otto, 78
 Selz-de Groot framework, problem-solving and, 78
 Semantic networks, 232
 Semantic reasoning, 37
 Semantic web, 235
 Sexism, 133
 Shanteau's framework, for decision making, 92
 Short-term memory (STM), 25, 39–43.
 See also Memory entries
 Sight-reading, musical perception and, 24, 26
 Simon, H. A., 29–33, 78–80, 85–86, 109–110, 240
 Simon's theory, of expert intuition, 98–99
 Simulated eye, 53*f*
 Situated action, experts and, 201
 Situational elements, of intuition expertise, 99
 Skill acquisition, in novices, 170–172, 174–176
 Skilled memory theory, 49
 Skills, generativity and, 242
 Sloboda, J. A., 24–27
 Slots
 encoding and, 232
 templates and, 54
 Slotted schemata, 57
 Smart drugs, intelligence, neuro-function and, 182–183
 Social closure, 203
 Society, experts and, 182–183
 believing experts, why?, 200–201
 expertise and, 243–244
 expertocracy, 193
 failure of experts, 187–188
 fraud/cheating, in science, 194–195
 group phenomena, 197–200
 Internet and, 196–197
 justice, miscarriage of and, 186–187
 media and, 193
 political science, predictions and, 190–192
 predictions, difficulty of making correct, 185–186
 scientific research and, 188–190
 situated action and, 201
 sports, cheating in, 195–196
 Sociocultural contexts, of creativity development, 107–108
 Socioeconomic conditions, creativity development and, 106
 Sociology
 diachronicity and, 243
 knowledge and, 241
 Socrates, 222
 SOS effect, decision making and, 91
 Spaghetti model, 244*f*
 Span of apprehension, 26
 Spatial ability, 123
 Spatial intelligence, 118
 Spearman, Charles, 116
 Spearman's theory of intelligence, 116, 117*f*
 Specialisation
 communication and, 207–208
 diversification in sports vs., 151–152
 expertise and, 248
 Specialisation effects, in expertise, 72–73
 Specialisation paradigm, 72–73, 193
 Specialist expertise, 211*t*, 212
 Specialist knowledge, 212
 Specialist tacit knowledge, 211*t*, 212–213
 Speed tasks, gender and, 135–136
 Spiral of improvement, 140
 Spiritual intelligence, 118

- Sports
 cheating in, 195–196
 expertise and, 246–248
 genetics, talent, performance and,
 124–126
 memory in, 46–47
 neuro-expertise and, 174–176
 perception in, 17–19
 specialisation vs. diversification in,
 151–152
 Sports, decision making in, 93–95
 option selection, 94–95
 task-specific probabilities, use, 93–94
 Standard deviations, 132
 Status, believing experts and, 200–201
 Statutory law, 209
 STEM disciplines, 119
 Stereotype threat, 133
 Stereotypical thinking, knowledge and,
 107
 STM. *See* Short-term memory
 Stories, communication and, 200
 Strategies, development and, 162
 Strict hierarchy, 232
 Super-expert, 5, 250–251
 Symbolic processing, 81
 System of playing method, 71
 Systems communication, 207
- T**
Tacit Dimension (Polanyi), 220
 Tacit knowledge, 215, 219–220
 Talent
 based on intelligence, 115–121. *See*
also Intelligence, talent and
 in chess, 121–123
 gender differences and, 131–136. *See*
also Gender differences
 genetics of, 149
 Geschwind and Galaburda's theory of,
 122
 gifted children and, 162–163
 in music, 123
 personality and, 127–129. *See also*
 Personality, talent and
 practice vs., 149, 245–246
 psychopathy and, 129–131
 in sports, 124–127
Talent Code, The (Coyle), 143
 Talent identification, 138–139
Talent is Overrated (Colvin), 143
 Tangled hierarchy, 232
 Task-specific probabilities, sports,
 decision making and, 93–94
 Teachers, expert, 153–155
 Team expertise, 250
 Techne (craft), 218
 Technical connoisseurship, 211*t*, 213
 Technocracy, 193
 Template theory
 CHREST, chunking and, 52–56
 evaluation of, 56–58
 of expert intuition, 100
 functional reorganisation of brain and,
 180
 principles of education, 140
 problem-solving and, 79–80
 Testimony, experts and, 208
 Testosterone exposure, in utero, talent
 and, 122, 180
 Theoretical discipline, 226
 Theoretical inferences, AI and, 112
 Theories, of memory, 48–60
 Thorndike and Woodworth's theory of
 identical elements, 150–151
 Thurstone, Louis, 116
 Time cost, of cognitive processes, 52
 Torrance's tests of creative thinking, 105
 Track record, 211*t*, 214
 Training
 creativity development and, 106–107
 deliberate practice and, 147
 functional reorganisation of brain and,
 180
 perceptual patterns and, 18, 23
 skill acquisition and, 170–172
 sports, neuro-expertise and, 174–176
 Trait approach, 205
 Transcranial magnetic stimulation
 (TMS), 172, 174, 175–176
 Transfer, 150–152
 differential predictions, of practice/
 talent, 150–152
 diversification, specialisation in sports
 and, 150–152
 expertise and, 250
 Transverse themes, in expertise,
 238–239
 Truly random positions, 39
 Trust, expertise and, 209
 Tutoring, 141–142
 Two-stage detection model, 15
- U**
 Ubiquitous discrimination, 211*t*, 213
 Ubiquitous expertises, 211*t*, 212
 Ubiquitous tacit knowledge, 211*t*,
 212, 215

- Unconscious mechanisms, creativity and, 108–109
- Unconscious processing, 234
- Understanding, learner's, 228
- United States v. Johnson*, 208
- V**
- Value, creativity and, 103
- Valuation phase, of problem-solving, 64
- Variability, measuring, 145
- VAX computer systems, 232–233
- Verbal communication, gender differences, 181–182
- Verbal IQ, 120, 135–136
- Verification stage, of creativity, 108
- Visual processing, 177
- Visual recall tasks, 25
- Visual search, 19
- Visuospatial delayed-match-to-sample task, 170–171
- Visuospatial domains, handedness and talent in, 122, 180
- Voxel-based morphometry, 175
- W**
- Water-level task, 76
- Watson, John, 142
- Weber, Max, 203–204
- Weighted probabilities, 64
- Weschler-Bellvue test, 90
- What Computers Can't Do: The Limits of Artificial Intelligence* (Dreyfus), 224, 241
- Win-stay hypothesis, 66
- Wisdom of Crowds, The* (Surowiecki), 197–200
- Witnesses, expert, 208–209
- X**
- XCON, expert system, AI and, 231–233