1 An Introduction to the Second Edition of *The Cambridge Handbook of Expertise and Expert Performance*: Its Development, Organization, and Content

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The study of expertise and expert performance reached a significant milestone in 2006 when its first handbook was published (Ericsson, Charness, Hoffman, & Feltovich, 2006). In the ten subsequent years, the handbook surpassed 10,000 copies sold, which is pretty impressive for a book of almost 1,000 pages. During this last decade there has been a dramatic increase in articles and books reporting on expertise and expert performance. There are several edited books written about particular domains of expertise, such as sports expertise (Baker & Farrow, 2015) and developing sports expertise (Farrow & Baker, 2013), entrepreneurial expertise (Sarasvathy, 2008), and design expertise (Lawson & Dorst, 2009). Other books have taken more general perspectives on the structure of expertise and its acquisition (Montero, 2016), the social aspects of how expertise is evaluated and experts evaluated (Collins & Evans, 2007), and the relation between skill acquisition and expertise (Johnson & Proctor, 2016). General books on the topics of expertise and expert performance have been published, focusing on professional development (Ericsson, 2009), accelerating the development of expertise (Hoffman et al., 2014), as noted earlier, and expertise in professional decision making (Hoffman, 2007). Another sign of impact is the large number of popular books describing how insights from the study of expertise and expert performance can inform individuals on how to improve their performance. A few examples of such popular books are Colvin (2008), Coyle (2009), Ericsson and Pool (2016), Foer (2011), Gladwell (2008), and Marcus (2012). This new edition of the handbook will update the most active areas of research and provide an up-to-date summary of our knowledge about perspectives, approaches, and methods in the study of expertise and expert performance as well as updated assessments of the knowledge of expertise and expert performance in different domains of expertise. There is also a new section identifying similar mechanisms that mediate expertise and expert performance across different domains, as well as generalizable issues and theoretical frameworks.

Expert, Expertise, and Expert Performance: Dictionary Definitions

Encyclopedias describe an ***Expert*** as “one who is very skillful and well-informed in some special field” (*Webster’s New World Dictionary*, 1968, p. 168), or “someone widely recognized as a reliable source of knowledge, technique, or skill whose judgment is accorded authority and status by the public or his or her peers. Experts have prolonged or intense experience through practice and education in a particular field” (Wikipedia). ***Expertise*** then refers to the characteristics, skills,

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and knowledge that distinguish experts from novices and less experienced people. In some domains there are objective criteria for finding experts, who are consistently able to exhibit superior performance for representative tasks in a domain. For example, chess masters will almost always win chess games against recreational chess players in chess tournaments, medical specialists are far more likely to diagnose a disease correctly than advanced medical students, and professional musicians can perform pieces of music in a manner that is unattainable for less skilled musicians. These types of superior reproducible performances on representative tasks capture the essence of the respective domains, and authors have been encouraged to refer to them as ***Expert Performance*** in this and the original handbook.

It has been known for some time that in some domains it is difficult for non-experts to identify experts, and consequently researchers rely on peer-nominations by professionals in the same domain. However, people recognized by their peers as experts do not always display superior performance on domain-related tasks. Sometimes they are no better than novices even on tasks that are central to the expertise, such as selecting stocks with superior future value, treatment of psychotherapy patients, and forecasts (Ericsson & Lehmann, 1996). There are several domains where experts disagree and make inconsistent recommendations for action, such as recommending selling versus buying the same stock. For example, expert auditors' assessments have been found to differ more from each other than the assessments of less experienced auditors (Bédard, 1991). Furthermore, experts will sometimes acquire differences from novices and other people as a function of their repetitive routines, that is, as a consequence of their extended experience rather than a cause for their superior performance. For example, medical doctors' handwriting is less legible than that of other health professionals (Lyons, Payne, McCabe, & Fielder, 1998). In sum, Shanteau (1988) suggested that "experts" may not need a proven record of performance and can adopt a particular image and project "outwards signs of extreme self-confidence" (p. 211) to get clients to listen to them and continue to offer advice after negative outcomes. After all, the experts are nearly always the best qualified to evaluate their own performance and explain the reasons for any deviant outcomes.

When the proposal for the first edition of the handbook was originally prepared, the outline focused more narrowly on the structure and acquisition of highly superior (expert) performance in many different domains (Ericsson, 1996, 2004). In response to the requests of the reviewers of that proposal, the final outline of the handbook covered a broader field that included research on the development of expertise and how highly experienced individuals accumulate knowledge in their respective domains and eventually become socially recognized experts and masters. Consequently, to reflect the scope of the handbook it was entitled *The Cambridge Handbook of Expertise and Expert Performance*. The first edition of the handbook thus included a multitude of conceptions of expertise, including perspectives from education, sociology, and computer science, along with the more numerous perspectives from psychology emphasizing basic abilities, knowledge, and acquired skills. In this second edition there is an even more committed effort to include new perspectives, such as the evolution of expertise over many millennia, the phenomenology of expertise, and even the concept of expertise in non-human animals, such as service dogs and dogs herding sheep. In this introductory chapter, I will briefly introduce some general issues and describe the structure and content of the handbook as it was approved by Cambridge University Press.

Tracing the Development of Our Knowledge of Expertise and Expert Performance

Since the beginning of Western civilization there has been particular interest in the superior knowledge that experts have acquired in their domain of expertise. The body of knowledge that experts accrue in their domain is a particularly important difference between experts and other individuals. Much of this knowledge can be verbally described and shared with others to benefit decision making in the domain and can help educate students and facilitate their progress toward expertise. The special status of the knowledge of experts in their domain of expertise is acknowledged even as far back as the Greek civilization. Socrates said that:

> I observe that when a decision has to be taken at the state assembly about some matter of building, they send for the builders to give their advice about the buildings, and when it concerns shipbuilding they send for the shipwrights, and similarly in every case where they are dealing with a subject which they think can be learned and taught. But if anyone else tries to give advice, who they don't regard as an expert, no matter how handsome or wealthy or well-born he is, they still will have none of him, but jeer at him and create an uproar, until either the would-be speaker is shouted down and gives up of his own accord, or else the police drag him away or put him out on the order of the presidents. (Plato, 1991, pp. 11–12)

Aristotle relied on his own senses as the primary source of scientific knowledge and sought out beekeepers, fishermen, hunters, and herdsmen to get the best and most reliable information for his books on science (Barnes, 2000). He even tried to explain occasional incorrect reports from some of his informants about how offspring of animals were generated. For example, some of them suggested that "the ravens and the ibises unite at the mouth" (Aristotle, 1943, p. 315). But Aristotle notes: "It is odd, however, that our friends do not reason out how the semen manages to pass through the stomach and arrive in the uterus, in view of the fact that the stomach concocts everything that gets into it, as it does the nourishment" (pp. 315 & 317). Similarly, "those who assert that the female fishes conceive as a result of swallowing the male's semen have failed to notice certain points" (p. 311). Aristotle explains that "Another point which helps to deceive these people is this. Fish of this sort take only a very short time over their copulation, with the result that many fishermen never even see it happening, for of course no fishermen ever watches this sort of thing for the sake of pure knowledge" (p. 313). Much of Aristotle's knowledge comes, at least partly, from consensus reports of professionals.

Much later during the Middle Ages, craftsmen formed guilds to protect themselves from competition. Through arrangements with the mayor and/or monarch they obtained a monopoly on providing particular types of handcraft and services with set quality standards (Epstein, 1991). They passed on their special knowledge of how to produce products, such as lace, barrels, and shoes, to their students (apprentices). Apprentices would typically start at around age 14 and commit to serve and study with their master for around seven years – the length of time varied depending on the complexity of the craft and the age and prior experience of the apprentice (Epstein, 1991). Once an apprentice had served out their contract they were given a letter of recommendation and were free to work with other masters for pay, which often involved traveling to other cities and towns – they were therefore referred to as journeymen. When a journeyman had accumulated enough additional skill and saved enough money he, or occasionally she, would often return to his home town to inherit or purchase a shop with tools and apply to become a master of the guild. In most guilds they required inspection of the journeyman's best work, i.e. master pieces, and in some guilds they administered special tests to assess the level of performance (Epstein, 1991). When people were accepted as masters they were held responsible for the quality of the products from their shop and were thereby allowed to take on the training of apprentices (see the chapter by Amirault & Branson, 2006, in the first edition of the handbook on the progression toward expertise and mastery of a domain).

In a similar manner, the scholars' guild was established in the twelfth and thirteenth centuries as "a *univeristas magistribus et pupillorum*," or "guild of masters and students" (Krause, 1996, p. 9). Influenced by the University of Paris, most universities conducted all instruction in Latin, where the students were initially apprenticed as arts students until they successfully completed the preparatory (undergraduate) program and were admitted to the more advanced programs in medicine, law, or theology. To become a master, the advanced students needed to satisfy "a committee of examiners," then publicly defend a thesis, often in the town square and with local grocers and shoemakers asking questions (Krause, 1996, p. 10). The goal of the universities was to accumulate and explain knowledge and in the process masters organized the existing knowledge (see Amirault & Branson, 2006). With the new organization of existing knowledge of a domain, it was no longer necessary for individuals to discover the relevant knowledge and methods by themselves.

Today's experts can rapidly acquire the knowledge originally discovered and accumulated by preceding expert practitioners by enrolling in courses taught by skilled and knowledgeable teachers using specially prepared textbooks. For example, in the thirteenth century Roger Bacon argued that it would be impossible to master mathematics by the then known methods of learning (self-study) in less than 30 to 40 years (Singer, 1958). Today the roughly equivalent material (calculus) is taught in highly organized and accessible form in every high school.

Sir Francis Bacon is generally viewed as one of the architects of the Enlightenment period of Western civilization and one of the main proponents of the benefits of generating new scientific knowledge. In 1620 he described in his book *Novum Organum* his proposal for collecting and organizing all existing knowledge to help our civilization engage in learning to develop a better world. In it, he appended a listing of all topics of knowledge to be included in *Catalogus Historarium Particularium*. It included a long list of skilled crafts, such as "History of weaving, and of ancillary skills associated with it," "History of dyeing," "History of leather-working, tanning, and of associated ancillary skills" (Rees & Wakely, 2004, p. 483).

The guilds guarded their knowledge and their monopoly of production. It is therefore not surprising that the same forces that eventually resulted in the French Revolution were not directed only at the oppression by the king and the nobility, but also against the monopoly of services provided by the members of the guilds. Influenced by Sir Francis Bacon's call for an encyclopedic compilation of human knowledge, Diderot and D'Alembert worked on assembling all available knowledge in the first *Encyclopédie* (Diderot & D'Alembert, 1966–67), which was published in 1751–80.

Diderot was committed to the creation of comprehensive descriptions of the mechanical arts to make their knowledge available to the public and encourage research and development in all stages of production and all types of skills, such as tanning, carpentry, glassmaking, and ironworking (Pannabecker, 1994) along with descriptions of how to sharpen a feather for writing with ink as shown in Figure 1.1. His goal was to describe all the raw materials and tools that were necessary, along with the methods of production. Diderot and his associate contributors had considerable difficulties gaining access to all the information because of the unwillingness of the guild members to answer their questions. Diderot even considered sending some of his assistants to become apprentices in the respective skills to gain access

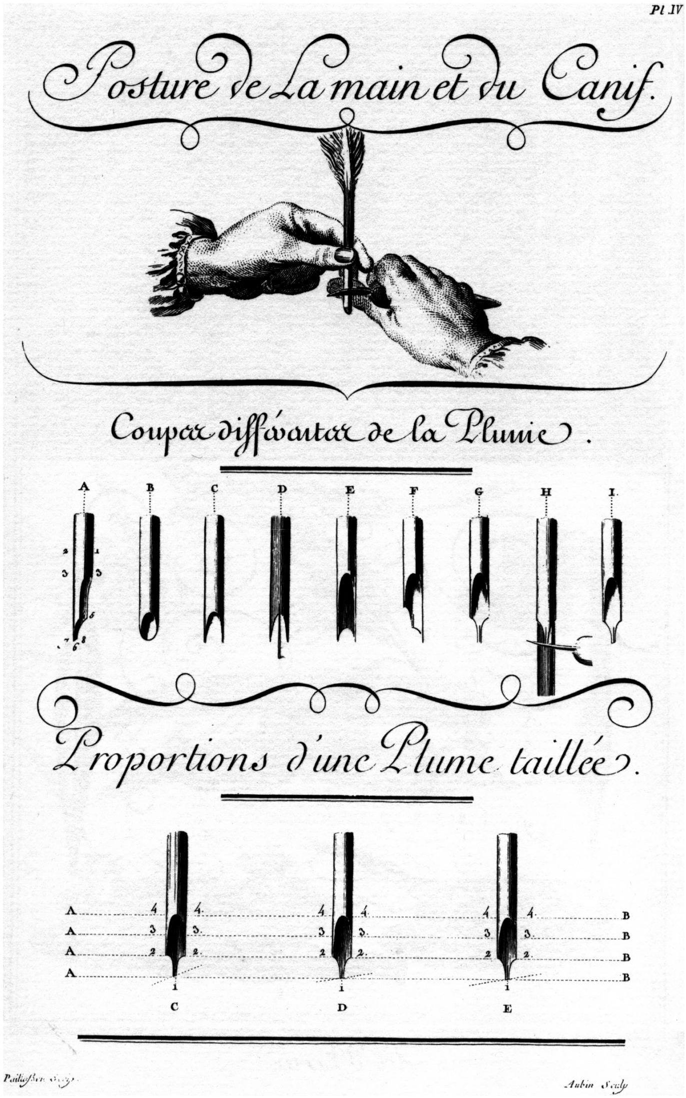

Figure 1.1 An illustration of how to sharpen a goose feather for writing with ink from Plate IV in the entry on "Ecriture" in the 23rd volume of *Encyclopédie ou dictionnare de raisonné des sciences, des arts et des métiers* (Diderot & D'Alembert, 1966–67).

to all the relevant information (Pannabecker, 1994). In spite of all the information and pictures (diagrams of tools, workspaces, procedures, etc. as illustrated in Figure 1.2 showing one of several plates of the process of printing) provided in the *Encyclopédie*, Diderot was under no illusion that the provided information would by itself allow anyone to become a craftsman in any of the described arts and wrote: "It is handicraft that makes the artist, and it is not in Books that one can learn to manipulate" (Pannabecker, 1994, p. 52). In fact, Diderot did not even address the higher levels of cognitive activity, "such as intuitive knowledge, experimentation, perceptual skills,

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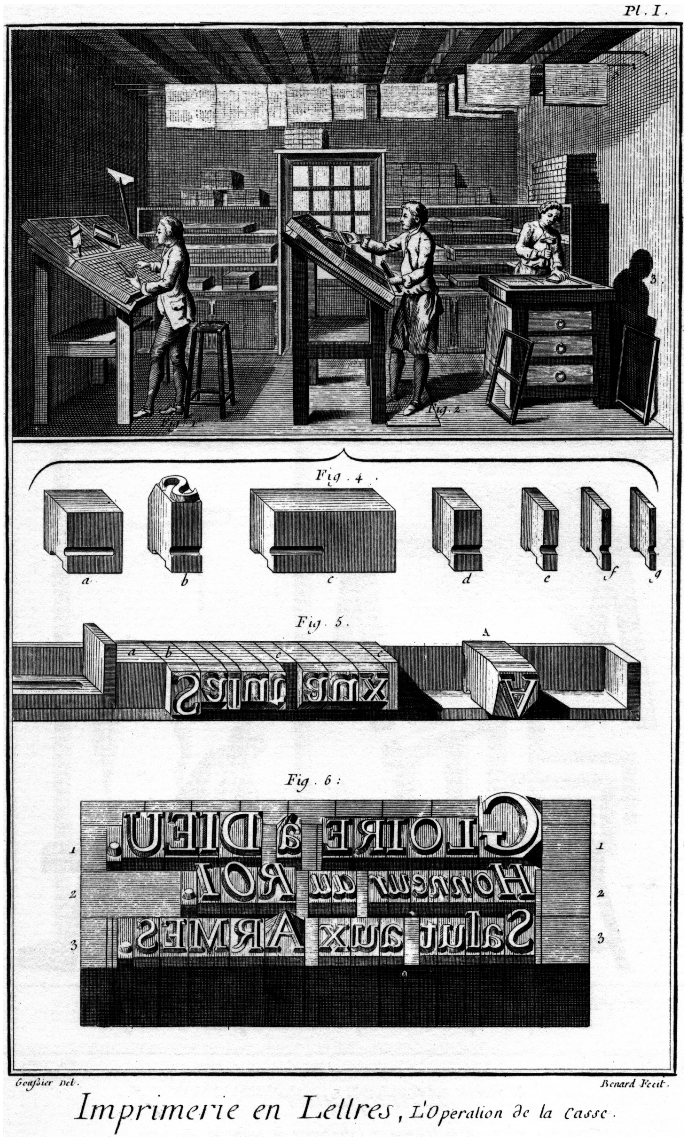

Figure 1.2 An illustration of the workspace of a printer with some of his type elements from Plate I in the entry on "Imprimerie" in the 28th volume of *Encyclopédie ou dictionnare de raisonné des sciences, des arts et des métiers* (Diderot & D'Alembert, 1966–67).

problem-solving, or the analysis of conflicting or alternative technical approaches" (Pannabecker, 1994, p. 52).

A couple of years after the French Revolution the monopoly of the guilds was eliminated (Fitzsimmons, 2003) including the restrictions on the practice of medicine and law. After the American Revolution and the creation of the United States of America laws were initially created to require that doctors and lawyers be highly trained based on the apprenticeship model, but pressure to eliminate elitist tendencies led to the repeal of those laws. From 1840 to the end of the nineteenth century there was no requirement for certification to practice medicine and law in the USA (Krause, 1996). However, with time both France and the USA realized the need to restrict vital medical and legal services to qualified professionals and developed procedures for training and certification.

Over the last couple of centuries there have been several major changes in the relation between master and apprentice. For example, before the middle of the nineteenth century children of poor families would often be taken on by teachers in exchange for a contractual claim for part of the future dancers', singers', or musicians' earnings as an adult (Rosselli, 1991). Since then the state has gotten more involved in the training of their expert performers, even outside the traditional areas of academia and professional training in medicine, law, business, and engineering. In the late nineteenth century public institutions, such as the Royal Academy of Music, were established to promote the development of very high levels of skill in music to allow native students to compete with better trained immigrants (Rohr, 2001). In a similar manner during the latter part of the twentieth century, many countries invested in schools and academies for the development of highly skilled athletes for improved success in competitions during the Olympic Games and World Championships (Bloomfield, 2004).

More generally, over the last century there have been economic developments with public broadcasts of competitions and performances that generate sufficient revenue for a number of domains of expertise, such as sports and chess, to support professional full-time performers as well as coaches, trainers, and teachers. In these new domains, along with the traditional professions, current and past expert performers continue to be the primary teachers at advanced levels (masters) and their professional associations have the responsibility for certifying acceptable performance and the permission to practice. Thus they have the clout to influence training in professional schools, such as law, medical, nursing, and business schools – "testing is the tail that wags the dog" (Feltovich, personal communication). The accumulation of knowledge about the structure and acquisition of expertise in a given domain as well as knowledge about instruction and training of future professionals have, until quite recently, occurred almost exclusively within each domain, with little cross-fertilization of domains in terms of teaching, learning methods, and skill training techniques.

It is not immediately apparent what is generalizable across such diverse domains of expertise as music, sport, medicine, and chess. What could possibly be shared by the skills of playing difficult pieces by Chopin, running a mile in less than four minutes, and playing chess at a high level? The premise for a field studying expertise and expert performance is that there are sufficient similarities in the theoretical principles mediating the phenomena and the methods for studying them in different domains that it would be possible to propose a general theory of expertise and expert performance. All of these domains of expertise have been created by humans and thus the accumulated knowledge and skills are likely to reflect similarities in structure reflecting human biological and psychological factors as well as cultural factors. This raises many challenging problems for methodologies seeking to describe the organization of knowledge and to identify the mechanisms mediating expert performance that generalize across domains.

Once we know how experts organize their knowledge and their performance, is it possible to improve the efficiency of learning to reach higher levels of expert performance in these domains? It should also be possible to determine why different individuals improve their performance at different rates and why different people reach very different levels of final achievement. Would a deeper understanding of the development and its mediating mechanisms make it possible to select individuals with unusual potential and to design better developmental environments to increase the proportion of performers who reach the highest levels? Would it even be possible to facilitate the development of those rare individuals who make major creative contributions to their respective domains?

Conceptions of Generalizable Aspects of Expertise

Several different theoretical frameworks have focused on broad issues on attaining expert performance that generalize across different domains of expertise.

Individual Differences in Mental Capacities

A widely accepted theoretical concept argues that general innate mental capacities mediate the attainment of exceptional performance in most domains of expertise. In his famous book, *Hereditary Genius*, Galton (1869/1979) proposed that across a wide range of domains of intellectual activity the same innate factors are required to attain outstanding achievement and designation as a genius. He analyzed eminent individuals in many domains in Great Britain and found that these eminent individuals were very often the offspring of a small number of families – with much higher frequency than could be expected by chance. The descendants from these families were much more likely to make eminent contributions in very diverse domains of activity, such as becoming famous politicians, scientists, judges, musicians, painters, and authors. This observation led Galton to suggest that there must be a heritable potential that allows some people to reach an exceptional level in any one of many different domains. After reviewing the evidence that height and body size were heritable Galton (1869/1979) argued: "Now, if this be the case with stature, then it will be true as regards every other physical feature – as circumference of head, size of brain, weight of gray matter, number of brain fibers, &c.; and thence, by a step on which no physiologist will hesitate, as regards *mental capacity*" (pp. 31–32, emphasis added).

Galton clearly acknowledged the need for training to reach high levels of performance in any domain. However, he argued that improvements are rapid only in the *beginning* of training and that subsequent increases become increasingly smaller, until "maximal performance becomes a rigidly determinate quantity" (p. 15). Galton developed a number of different mental tests of individual differences in mental capacity. Although he never related these measures to objective performance of experts on particular real-world tasks, his views led to the common practice of using psychometric tests for admitting students into professional schools and academies for arts and sports with severely limited availability of slots. These tests of basic ability and talent were believed to identify the students with the capacity for reaching the highest levels.

In the twentieth century scientists began testing large groups of experts to measure their powers of mental speed, memory, and intelligence with psychometric tests. When the experts' performances were compared to control groups of comparable education there was no evidence supporting Galton's hypothesis of a general superiority for experts, because the demonstrated superiority of experts was found to be specific to certain aspects related to the particular domain of expertise. For example, the superiority of the chess expert's memory was constrained to regular chess positions and did not generalize to other types of materials (Djakow, Petrowski, & Rudik, 1927). Not even IQ could distinguish the best among chess players (Doll & Mayr, 1987) nor the most successful and creative among artists and scientists (Taylor, 1975).

In an article in the *Annual Review of Psychology*, Ericsson and Lehmann (1996) found that (1) measures of basic mental capacities are not valid predictors of attainment of expert performance in a domain, (2) the superior performance of experts is often very domain specific and transfer outside their narrow area of expertise is surprisingly limited, and (3) systematic differences between experts and less proficient individuals nearly always reflect attributes acquired by the experts during their lengthy training. Since the first edition of this book there have been several special issues directed to the discussion of various factors influencing the development of expert performance, such as a special issue of the *International Journal of Sport Psychology* on “Nature, Nurture, and Sport Performance” (Baker & Davids, 2007), a special issue of *High Ability Studies* on “Expertise and Giftedness Research” (Stoeger, 2007), and a special issue of *Intelligence* on “Acquiring Expertise: Ability, Practice, and Other Influences” (Detterman, 2014).

Expertise as the Extrapolation of Everyday Skill to Extended Experience

A second general type of theoretical framework is based on the assumption that the same learning mechanisms that account for the acquisition of everyday skills can be extended to the acquisition of higher levels of skills and expertise. Studies in the nineteenth century proposed that the acquisition of high levels of skills was a natural consequence of extended experience in the domains of expertise. For example, Bryan and Harter (1899) argued that ten years of experience were required to become a professional telegrapher. The most influential and pioneering work on expertise was conducted in the 1940s by Adrian de Groot (1978), who invited international chess masters and skilled club players to “think aloud” while they selected the best move for chess positions. His analyses of the protocols showed that the elite players were able to recognize and generate chess moves that were superior to skilled club players by relying on acquired patterns and planning. De Groot’s dissertation was later translated into English in the late 1960s and early 1970s (de Groot, 1978) and had substantial impact on the seminal theory of expertise proposed by Herb Simon and Bill Chase (Simon & Chase, 1973).

In the 1950s and 1960s Newell and Simon proposed how information processing models of human problem-solving could be implemented as computer programs, such as the General Problem Solver (Ernst & Newell, 1969). In their seminal book, *Human Problem Solving*, Newell and Simon (1972) argued that domain-general problem-solving was limited and that thinking involved in solving most tasks could be represented as the execution of a sequence of production rules, such as IF <pattern>, THEN <action> that incorporated specific knowledge about the task environment. In their theory of expertise, Simon and Chase (1973) made the fundamental assumption that the same patterns (chunks) that allowed the experts to retrieve suitable actions from memory were the same patterns that mediated experts’ superior memory for the current situation in a game.

Chase and Simon (1973) redirected the focus of research toward studying performance on memory tasks as a more direct method of studying the characteristics of patterns that mediate improvement in skill. They found that there was a clear relation between the number of chess pieces recalled from briefly presented chess positions and the player’s level of chess expertise. Grand masters were almost able to reproduce entire chessboards (24–26 pieces) by recalling a small number of complex chunks whereas novices could only recall around four pieces, where each piece was a chunk. The masters’ superior memory was assumed to depend on an acquired body of many different patterns in memory, because their memory for randomly rearranged chess configurations was markedly reduced. In fact, they could only recall around five to seven pieces, which was only slightly better than the recall of novices.

Experts’ superiority for representative but not randomly rearranged stimuli has since been

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demonstrated in a large number of domains. The relation between the mechanisms mediating memory performance and the ones mediating representative performance in the same domains has been found to be much more complex than originally proposed by Simon and Chase (1973) (for a more up-to-date review on the topic of experts' superior memory for representative information in their domain see Ericsson, Chapter 36, and Gobet & Charness, Chapter 31, this volume).

Expertise as Qualitatively Different Representation and Organization of Knowledge

A different family of approaches drawing on the Simon–Chase theory of expertise has focused on the content and organization of the experts' knowledge (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982) and on methods to extract the experts' knowledge to build computer-based models emulating the experts' performance (Hoffman, 1992). These approaches have studied experts, namely individuals who are socially recognized as experts and/or distinguished by their extensive experience (typically over ten years) and by knowledge of a particular subject attained through instruction, study, or practical experience. The work of Micheline Chi, Paul Feltovich, and Robert Glaser (1981) examined the representations of knowledge and problem solutions in academic domains, such as physics. Of particular importance, Chi (1981) studied children with extensive knowledge of chess and dinosaurs and found these children displayed many of the same characteristics of the knowledge representations of adult experts. This work on expertise is summarized in this volume by Feltovich, Prietula, and Ericsson, Chapter 6, and Lintern, Moon, Klein, and Hoffman, Chapter 11.

In a parallel development in computer science of the late 1970s and early 1980s, Edward Feigenbaum and other researchers in the area of artificial intelligence and cognitive science attempted to elicit the knowledge of experts (Hoffman, 1992) and to incorporate their knowledge in computer models (expert systems) that sought to replicate some of the decision making and behavior of experts (see in this volume Buchanan, Davis, Smith, & Feigenbaum, Chapter 7, and Lintern et al., Chapter 11). There has been a long-standing controversy over whether highly experienced experts are capable of articulating the knowledge and methods that control their generation of appropriate actions in complex situations.

The tradition of skill acquisition of Bryan and Harter (1899), Fitts and Posner (1967), and Simon and Chase (1973) assumed that expert performance was associated with automation and virtually effortless performance based on pattern recognition and direct access of actions. However, Polanyi (1962, 1966) is generally recognized as the first critic who saw that nonconscious and intuitive mediation limits the possibility of eliciting and mapping the knowledge and rules that mediated experts' intuitive actions. Subsequent discussion of the development of expertise by Dreyfus and Dreyfus (1986) and Benner (1984) has argued that the highest levels of expertise are characterized by contextually based intuitive actions that are difficult or impossible to report verbally. Several chapters in this handbook propose methods for uncovering tacit knowledge about successful development of expertise (Cianciolo & Sternberg, Chapter 39), about methods of work through observation (Clancey, 2006), critical incident reports, concept maps, and decision ladders (Lintern et al., Chapter 11), reaction times to perceptual stimuli (Landy, Chapter 10), superior anticipation of opponents' action (Abernethy, Farrow, & Mann, Chapter 35), and traditional psychometric analyses of individual differences in traits related to attained performance (Ackerman & Beier, Chapter 13). Other investigators have collected concurrent verbal reports (think-aloud protocols) to monitor the experts' performance while they respond to representative situations from their domain (Ericsson, Chapter 12). These verbalized thoughts have raised issues about how experts have acquired memory skills to allow them to maintain efficient access to diverse information relevant to the generation of performance (long-term working memory, Ericsson, Chapter 36, and situational awareness, Endsley, Chapter 37). This latter evidence on expertise suggests that expert performers have to actively retain and refine their mental representations for monitoring and controlling their performance.

Expertise as Elite Achievement Resulting from Superior Learning Environments

There are other approaches to the study of expertise that have focused on objective achievement. There is a long tradition of influential studies with interviews of peer-nominated eminent scientists (Roe, 1952) and analyses of biographical data on Nobel Prize winners (Zuckerman, 1977) (see Simonton, 1994, for a more extensive account). In a seminal study, Benjamin Bloom and his colleagues (Bloom, 1985a) interviewed international-level performers from six different domains of expertise ranging from swimming to molecular genetics. All of the 120 participants had won prizes at international competitions in their respective domains. They were all interviewed about their development, along with their parents, teachers, and coaches. For example, Bloom and his colleagues collected information on the development of athletes who had won international competitions in swimming and tennis. They also interviewed artists who had won international competitions in sculpting and piano playing and scientists who had won international awards in mathematics and molecular biology. In each of these six domains Bloom (1985b) found evidence for uniformly favorable learning environments for the participants in all the domains. Bloom (1985b) concluded that the availability of early instruction and support by their families appeared to be necessary for attaining an international level of performance as an adult. He found that the elite performers typically started early to engage in relevant training activities in the domain and were supported both by exceptional teachers and by committed parents. These topics are covered in this handbook through up-to-date reviews of historiometric approaches to the development of professional excellence (Simonton, Chapter 18) and of case studies of experts (Mumford, McIntosh, & Mulhearn, Chapter 17). In a new addition to the handbook Elferink-Gemser, te Wierike, and Visscher (Chapter 16) review longitudinal studies of large groups of expert performers.

Expertise as Reliably Superior (Expert) Performance on Representative Tasks

It is difficult to identify the many mediating factors that might have been responsible for an elite performer to win an award and to write a groundbreaking book. When eminence and expertise are based on a singular or small number of unique creative products, such as books, paintings, or music compositions, it is rarely possible to identify and scientifically study the key factors that allowed these people to produce these achievements. Consequently, Ericsson and Smith (1991) proposed that the study of expertise with laboratory rigor requires representative tasks that capture the essence of expert performance in a specific domain of expertise. For example, a world-class sprinter will be able to reproduce superior running performance on many tracks and even indoors in a large laboratory. Similarly, de Groot (1978) found that the ability to select the best move for presented chess positions is the best correlate of chess ratings and performance at chess tournaments – a finding that was replicated (van der Maas & Wagenmakers, 2005). Once it is possible to reproduce the reliably superior performance of experts in a controlled setting, such as a laboratory, it then becomes feasible to examine the specific mediating mechanisms with experiments and process-tracing techniques, such as think-aloud verbal reports (see Ericsson, Chapter 12, in this volume, and Ericsson & Smith, 1991). The discovery of representative tasks that measure adult expert performance under standardized conditions in a controlled setting, such as a laboratory, makes it possible to measure and compare the performance of less skilled individuals on the same tasks. Even more importantly, it allows scientists to test aspiring performers many times during their development of expertise, allowing the measurement of gradual increases in performance.

The new focus on measurement of expert performance with standardized tasks revealed that "experts," i.e. individuals identified by their reputation or their extensive experience, are not always able to exhibit reliably superior performance. There are at least some domains where "experts" perform no better than less trained individuals and that sometimes experts' decisions are no more accurate than beginners' decisions and simple decision aids (Bolger & Wright, 1992; Camerer & Johnson, 1991). Most individuals who start as active professionals or as beginners in a domain change their behavior and increase their performance for a limited time until they reach an acceptable level. Beyond this point, however, further improvements appear to be unpredictable and the number of years of work and leisure experience in a domain is a poor predictor of attained performance (Ericsson & Lehmann, 1996). Hence, continued improvements (changes) in achievement are not automatic consequences of more experience and, in those domains where performance consistently increases, aspiring experts seek out particular kinds of training tasks designed for the particular performers by their teachers and coaches (deliberate practice) (Ericsson, Krampe, & Tesch-Römer, 1993). Several chapters in this revised handbook describe how deliberate practice can change the mechanisms mediating the experts' superior performance and that the accumulated amounts of deliberate practice are related to attained level of performance (see Ericsson, Chapter 38). Baker, Hodges, and Wilson (Chapter 15) review methods for collecting information about practice activities using concurrent and retrospective methods.

General Comments

In summary, there are a broad range of approaches to the study of the structure and acquisition of expertise as well as expert performance. Although individual researchers and editors may be primarily pursuing one of the approaches, this handbook has been designed to cover a wide range of different approaches and research topics in order to allow authors to describe their own views. However, the authors have been encouraged to describe explicitly their empirical criteria for their key concepts, such as expertise, experts, and expert performance. For example, the authors have been asked to report if the cited research findings involve experts identified by social criteria, criteria of lengthy domain-related experience, or criteria based on reproducibly superior performance on a particular set of tasks representative of the individuals' domain of expertise.

General Outline of the Handbook

The second edition of this handbook is organized into seven general sections. First, Part I introduces the handbook with brief accounts of general perspectives on expertise. In addition to this introductory chapter that outlines the organization of the handbook, there are four chapters. All of the four chapters are important new additions to the handbook. Collins and Evans (Chapter 2) give a sociological perspective of expertise based on philosophical analysis, Dall'Alba (Chapter 3) describes expertise from a phenomenological perspective based on the concept of the lifeworld, and Winegard, Winegard, and Geary (Chapter 4)

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take an evolutionary perspective on expertise and distinguish natural expertise, such as hunting, from non-functional expertise, such as chess. Finally Helton and Helton (Chapter 5) describe expertise displayed by non-humans, such as trained dogs detecting illegal drugs or herding livestock.

Part II of the revised handbook contains reviews of the historical development of the study of expertise from the perspective of different disciplines. Feltovich, Prietula, and Ericsson (Chapter 6) review the recurrent themes in the study of expertise from a psychological perspective. Buchanan, Davis, Smith, and Feigenbaum (Chapter 7) trace the historical development of using computers to model expertise, especially in the form of expert and knowledge-based systems. Billett, Harteis, and Gruber (Chapter 8) describe occupational expertise and its development based on experiences in the workplace. Finally, Mieg and Evetts (Chapter 9) describe the historical development of professionals and experts from a social perspective.

The next two sections of the handbook review the core methods for studying the structure (Part III) and acquisition (Part IV) of expertise and expert performance. Part III focuses on how expertise and expert performance can be explained by observable differences between experts and novices. In the first chapter in this section David Landy (Chapter 10) describes how the development of expertise can influence even processes of perception. Lintern et al. (Chapter 11) describe how the knowledge of experts has been elicited using the critical incident method, concept maps, and decision ladders. Ericsson (Chapter 12) describes the method of protocol analysis, which involves eliciting and recording the thought processes of experts when they respond to representative tasks from their domain of expertise. Ackerman and Beier (Chapter 13) describe psychometric approaches to expertise and identifying traits (cognitive, affective, and conative) that predict individual differences in its development. Finally Bilalić and Campitelli (Chapter 14) review methods to study changes in the neural structure and pattern of activation of the brain associated with expertise.

Part IV contains chapters examining methods for studying how skill, expertise, and expert performance develop and their relation to practice and other types of activities during the development. In the first chapter, Baker et al. (Chapter 15) describe methods and findings related to concurrent and retrospective assessment of these activities to performance. Elferink-Gemser et al. (Chapter 16) review the methodology and findings from longitudinal studies of groups of individuals developing achievement and performance. Mumford et al. (Chapter 17) describe how the case method for studying individuals' development can inform about the acquisition of expertise and expert performance. In the final chapter of this section, Dean Simonton (Chapter 18) reviews the methods of historiometrics and how data about the development of eminent performers can be collected and analyzed.

Part V consists of 16 chapters that provide up-to-date reviews of our current knowledge about expertise and expert performance in particular domains and represents the core of this handbook. The chapters in Part V have been broken down into two subsections. Part V.I is focused on different types of professional expertise. In the first chapter Norman, Grierson, Sherbino, Hamstra, Schmidt, and Mamede (Chapter 19) review our rapidly expanding knowledge about expertise in medicine and surgery as well as new training methods including simulators. Durso, Dattel, and Pop (Chapter 20) review the new research on expertise in transportation, especially driving and the effect of experience and training on hazard perception. In a completely new addition to the handbook Cross (Chapter 21) describes the new emerging domain of expertise in design based on studies with interviews and protocol analysis. In another new addition Dew, Ramesh, Read, and Sarasvathy (Chapter 22) review the knowledge of expertise among entrepreneurs and focus on the skill of requesting resources for new projects (The Ask). Kellogg (Chapter 23) has updated and expanded his review of expertise among professional writers and emphasizes the importance of other factors than writing ability such as knowledge of the topic and accessible memory for the already generated text. In a new addition Stigler and Miller (Chapter 24) review the societally important topic of expertise among teachers and identify the "pseudo expertise in teaching" as an obstacle to progress and outline how teachers can be helped to become more effective in improving their students' performance. Mosier, Fischer, Hoffman, and Klein (Chapter 25) describe the Naturalistic Decision Making approach to the examination and training of expert decision making in complex dynamic situations in everyday life. In a new addition to the handbook Cokely, Feltz, Ghazal, Allan, Petrova, and Garcia-Retamero (Chapter 26) review evidence on general decision making abilities that generalize across everyday contexts, finding that superior decision performance among both experts and non-experts primarily results from acquired specialized knowledge and probabilistic inductive reasoning skills (statistical numeracy and risk literacy). In the last chapter of Part V.I Sonesh, Lacerenza, Marlow, and Salas (Chapter 27) review the emerging evidence on how expert teams are more than the sum of all team members' expertise and emphasize the importance of the teams' adaptability, shared cognition, and leadership.

Part V.II contains chapters that review expert performance in the more traditional domains of games, such as chess, the arts, such as music, and sports. In the first chapter of the subsection Lehmann, Gruber, and Kopiez (Chapter 28) provide an updated review on the development of expert performance in music and its relation to the age of starting practice and the quality/quantity of different types of practice. Altenmüller and Furuya (Chapter 29) review evidence for the view that favorable adaptations of the brain are associated with superior performance and how maladaptive changes of the brain due to overtraining can account for the inability to control music playing, such as violinist's cramp. For the domains of drawing and painting Kozbelt and Ostrofsky (Chapter 30) examine the evidence for differences in general and specific perceptual and motor processes as a function of level of artistic skill. The classic domain of chess expertise is reviewed by Gobet and Charness (Chapter 31), who examine factors associated with individual differences in the ability to select superior chess moves, such as age of starting practice and amount of accumulated practice. Butterworth (Chapter 32) describes the evidence primarily on the development of expertise in mathematical calculation and discusses the effects of mental ability (natural ability), motivation (zeal), and practice (hard work). In a new addition to the handbook Macis, Garnier, Vilkaitė, and Schmitt (Chapter 33) review evidence on expertise in a foreign language by examining the development of learning and mastery of the critical vocabulary. In the final chapter of Part V.II Williams, Ford, Hodges, and Ward (Chapter 34) review expertise in sports and focus on the specificity and adaptability of expert athletes.

Part VI of the handbook is a new addition and addresses an important issue in the study of expertise and expert performance. In spite of the specificity of superior performance in a given domain, is it possible to identify mechanisms mediating performance in different domains which reveal a similar abstract structure? In the first chapter of this section Abernethy et al. (Chapter 35) show how the superior speed of reacting by experts compared to less skilled individuals can be accounted for by earlier anticipation of opponents' actions and better control and organization of their acquired motor processes. Ericsson (Chapter 36) shows how experts develop skills to maintain rapid access to information relevant to their current situations (long-term working memory). In the last chapter of Part VI Endsley (Chapter 37) reviews the research on experts' superior mental models based on perception, comprehension of the current situation, and prediction of future situations (situation awareness).

In Part VII the focus is on general theoretical issues that cut across different domains of expertise to provide reviews of the current state of knowledge. The first chapter, by Ericsson (Chapter 38), reviews the effects on attained performance from engagement in different types of domain-related activities, such as playing games, professional experience, solitary practice, and deliberate practice led by a teacher or coach. Cianciolo and Sternberg (Chapter 39) provide an updated review of the relation between expertise and central concepts/frameworks, such as practical intelligence, tacit knowledge, and related ecological theories. In a new addition Kalyuga and Sweller (Chapter 40) describe how instructional supports reduce cognitive load and improve learning for novice learners, but the same supports reduce the rate of further learning by more knowledgeable individuals and experts (the expertise reversal effect). Weisberg (Chapter 41) discusses the mechanisms mediating creative advances and shows how the expertise view provides superior accounts of the source of creativity. In the last chapter of the handbook, Krampe and Charness (Chapter 42) review the effects of aging deficits on tests of general cognitive ability for older participants. They find that these types of reduced performance on tests do not inevitably lead to reduced performance of experts, who are able to counteract reduction in the performance effects of aging with goal-directed practice.

Conclusion

This second edition of the handbook was designed to provide researchers, students, teachers, coaches, and anyone interested in attaining expertise with an up-to-date comprehensive reference to methods, findings, mechanisms, and theories related to expertise and expert performance. It is designed to be an essential tool for researchers, professionals, and students involved in the study or the training of expert performance and a necessary source for college and university libraries as well as public libraries. In addition, the volume is designed to provide a suitable text for graduate courses on expertise and expert performance. More generally, it is likely that professionals, graduate students, and even undergraduates who aspire to higher levels of performance in a given field can learn from experts' pathways to superior performance in similar domains.

Many researchers studying expertise and expert performance are excited and personally curious about the established research finding that most types of traditional expertise in competitive activities require years and decades of extended efforts to improve in order to acquire the mechanisms mediating world-class performance. There is considerable knowledge that is accumulating across many domains about the acquisition and refinement of these mechanisms during an extended period of training and practice. The generalizable insights range from the characteristics of ideal training environments with teachers and coaches, to the methods for fostering motivation by providing both emotional support and attainable training tasks of a suitable difficulty level. This theoretical framework has several implications.

It implies that if someone is interested in the upper limits of human performance, and the most effective training to achieve the highest attainable levels, they should study the training techniques and performance limits of experts who have spent their entire life striving to maximize their performance in a particular domain. This assumption also implies that the study of expert performance will provide us with the best current evidence on what is humanly possible to change and improve with today's methods of training and how these elite performers are able to achieve their highest levels of performance. Given that performance levels are increasing over decades and centuries in most domains of expertise, scientists will need to work with elite performers and their coaches to discover jointly the ever-increasing levels of improved performance.

The framework has implications for education and professional training of performance for all the introductory levels that eventually lead up to the expert levels in professional domains of expertise. By examining how the prospective expert performers attained their initial beginning levels of achievement, we should be able to develop practice environments and foster learning methods that help people to attain the fundamental representations of the tasks and the self-regulatory skills that are necessary for the prospective experts to advance their learning to higher levels.

With the rapid changes in the relevant knowledge and techniques required for most jobs nearly everyone will have to be capable of continuing their learning and even intermittently relearn aspects of their professional skills. The lifelong quest for improved adaptation to task demands will not be restricted to experts anymore. In order to be productive members of society we will all be encouraged to adopt the characteristics and the methods of the expert performers who continuously strive to attain and maintain their best level of achievement.

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