Part I

INTRODUCTION AND PERSPECTIVE

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CHAPTER 1

An Introduction to *Cambridge Handbook of Expertise and Expert Performance*: Its Development, Organization, and Content

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A significant milestone is reached when a field of scientific research matures to a point warranting publication of its first handbook. A substantial body of empirical findings, distinctive theoretical concepts and frameworks, and a set of new or adapted methods justify a unifying volume. The growth of this field is evident from the publication of a series of edited books on diverse sets of skills and expertise from many domains during the last several decades (Anderson, 1981; Bloom, 1985a; Chase, 1973; Chi, Glaser, & Farr, 1988; Ericsson, 1996a; Ericsson & Smith, 1991a; Feltovich, Ford, & Hoffman, 1997; Hoffman, 1992; Starkes & Allard, 1993; Starkes & Ericsson, 2003). And as in many other fields, the name of a branch of scientific study, in our case expertise and expert performance, often communicates the domain of studied phenomena.

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, 2005). ***Expertise*** then refers to the characteristics, skills, 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 of representative tasks capture the essence of the respective domains, and authors have been encouraged to refer to them as ***Expert Performance*** in this handbook.

In some domains it is difficult for nonexperts 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, which is 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). Finally, Shanteau (1988) has suggested that "experts" may not need a proven record of performance and can adopt a particular image and project "outward 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 this *Handbook* was originally prepared, the outline focused more narrowly on the structure and acquisition of highly superior (expert) performance in many different domains (Ericsson, 1996b, 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 current handbook thus includes 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 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 a particular interest in the superior knowledge that experts have in their domain of expertise. The body of knowledge associated with the domain of expertise in which a person is expert 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, whom 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, 2000, 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 even never 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 7 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, that is, 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 Amirault & Branson, Chapter 5, and Chi, Chapter 2, on the progression toward expertise and mastery of a domain).

In a similar manner, the scholars' guild was established in the 12th and 13th century as "a *universitas 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 defending 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, Chapter 5). With the new organization of the 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 13th 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 directed not 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 *Encyclopedie* (Diderot & D'Alembert, 1966–67), which was originally 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 to encourage research and development in all stages of production and all types of skills, such as tannery, 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 to all the relevant information (Pannabecker, 1994). In spite of all the information and pictures (diagrams of tools, workspaces, procedures, etc., as is illustrated in Figure 1.2 showing one of several plates of the process of printing) provided in the *Encyclopedie*, 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, 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 as 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 19th century there was no requirement for certification to practice medicine and law in the United States (Krause, 1996). However, with time both France and America realized the need to restrict vital medical and legal services to qualified professionals and developed procedures for training and certification.

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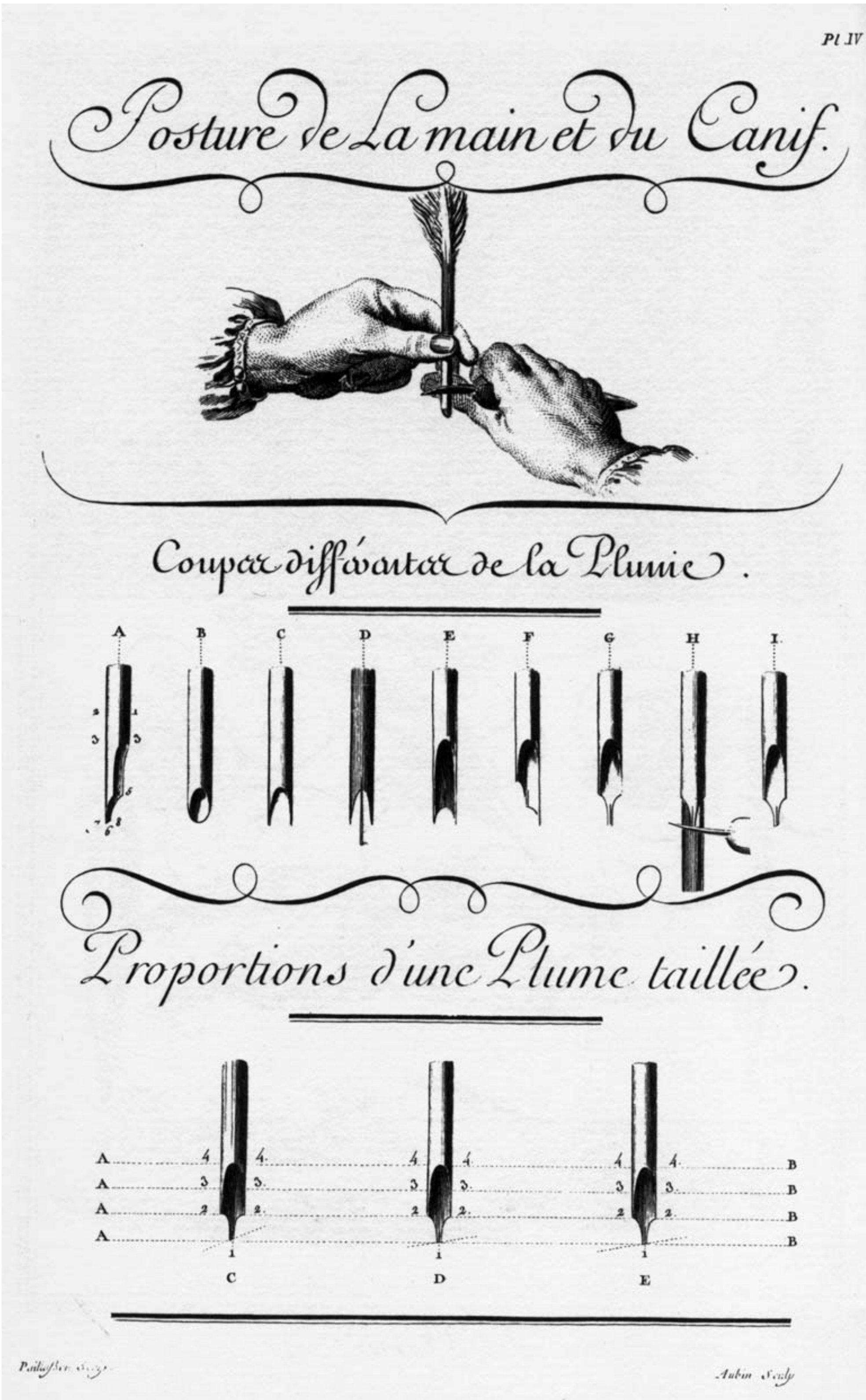

Figure 1.1. An illustration for how to sharpen a goose feather for writing with ink from Plate IV in the entry on "Ecriture" in the 23rd volume of *Encyclopedie ou dictionnare de raisonne des sciences, des artes et des métier* (Diderot & D'Alembert, 1966–67).

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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 *Encyclopedie ou dictionnare de raisonne des sciences, des artes et des métier* (Diderot & D'Alembert, 1966–67).

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 19th 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 19th 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 compete with better trained immigrants (Rohr, 2001). In a similar manner during the latter part of the 20th 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 the advanced level (masters), and their professional associations have the responsibility of certifying acceptable performance and the permission to practice. Accordingly, they hold the clout in thus influencing training in professional schools, such as law, medical, nursing, and business schools – "testing is the tail that wags the dog" (Feltovich, personal communication) – as well as continuing education training (see Evetts, Meig, & Felt, Chapter 7 on sociological perspectives on expertise). The accumulation of knowledge about the structure and acquisition of expertise in a given domain, as well as knowledge about the instruction and training of future professionals, has occurred, until quite recently, 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, such 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. Thus the accumulated knowledge and skills are likely to reflect similarities in structure that reflect both human biological and psychological factors, as well as cultural factors. This raises many challenging problems for methodologies used to describe the organization of knowledge and mechanisms and reveals the mediating expert performance that generalizes 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 answer 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 be possible even 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, "*Heriditary Genius*," Galton (1869/1979) proposed that across a wide range of domains of intellectual activity the same innate factors were required to attain outstanding achievement and the designation of being 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 descendents 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 grey matter, number of brain fibres, &c.; and thence, 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 the 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 20th century scientists began the psychometric testing of large groups of experts to measure their powers of mental speed, memory, and intelligence. When the experts' performance was compared to control groups of comparable education, there was no evidence for Galton's hypothesis of a general superiority for experts because the demonstrated superiority of experts was found to be limited to specific aspects related to the particular domain of expertise. For example, the superiority of the chess experts' 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) or the most successful and creative among artists and scientists (Taylor, 1975).

In a recent review, 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. The reader is directed to the chapter by Horn and Masunaga (chapter 34) and to comprehensive reviews in Sternberg and Grigorenko, 2003, and Howe, Davidson, and Sloboda. 1998.

Expertise as the Extrapolation of Everyday Skill to Extended Experience

A second general type of theoretical frameworks 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 19th 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 (see Gobet & Charness, chapter 30, and Ericsson, chapter 13, for a more detailed account). DeGroot's dissertation was later translated into English in the late 1960s and early 1970s (deGroot, 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 the 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. Instead of studying the representative task of playing chess, namely, selecting the best moves for chess positions (Ericsson & Smith, 1991b; Vicente & Wang, 1998), Chase and Simon (1973) redirected the focus of research toward studying performance of 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 able to reproduce almost the entire chessboards (24 to 26 pieces) by recalling a small number of complex chunks, whereas novices could recall only around 4 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 in such configurations they could recall only around 5 to 7 pieces, which was only slightly better than the recall of novices.

Experts' superiority for representative but not randomly rearranged stimuli has since been demonstrated in a large number of domains. The relation between the mechanisms mediating memory performance and the mechanisms mediating representative performance in the same domains have been found to be much more complex than originally proposed by Simon and Chase (1973) (see Gobet & Charness, Chapter 30, and Wilding & Valentine, Chapter 31. See also Ericsson & Kintsch, 1995; Ericsson, Patel, & Kintsch, 2000; Gobet & Simon, 1996; Simon & Gobet, 2000; Vicente & Wang, 1998).

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