CHAPTER 2

Two Approaches to the Study of Experts' Characteristics

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This chapter differentiates two approaches to the study of expertise, which I call the "absolute approach" and the "relative approach," and what each approach implies for how expertise is assessed. It then summarizes the characteristic ways in which experts excel and the ways that they sometimes seem to fall short of common expectations.

Two Approaches to the Study of Expertise

The nature of expertise has been studied in two general ways. One way is to study truly exceptional people with the goal of understanding how they perform in their domain of expertise. I use the term *domain* loosely to refer to both informal domains, such as sewing and cooking, and formal domains, such as biology and chess. One could choose exceptional people on the basis of their well-established discoveries. For example, one could study how Maxwell constructed a quantitative field concept (Nersessian, 1992). Or one could choose contemporary scientists whose breakthroughs may still be debated, such as pathologist Warren and gastroenterologist Marshall's proposal that bacteria cause peptic ulcers (Chi & Hausmann, 2003; Thagard, 1998; also see the chapters by Wilding & Valentine, Chapter 31, Simonton, Chapter 18, and Weisberg, Chapter 42).

Several methods can be used to identify someone who is truly an exceptional expert. One method is retrospective. That is, by looking at how well an outcome or product is received, one can determine who is or is not an expert. For example, to identify a great composer, one can examine a quantitative index, such as how often his or her music was broadcast (Kozbelt, 2004). A second method may be some kind of concurrent measure, such as a rating system as a result of tournaments, as in chess (Elo, 1965), or as a result of examinations (Masunaga & Horn, 2000), or just measures of how well the exceptional expert performs his task. A third method might be the use of some independent index, if it is available. In chess, for example, there exists a task called the Knight's Tour that requires a player to move a Knight Piece across the rows of a chess board, using legal Knight Moves. The time it

Table 2.1. A proficiency scale (adapted from Hoffman, 1998).

Naive	*One who is totally ignorant of a domain*
Novice	Literally, someone who is new – a probationary member. There has been some minimal exposure to the domain.
Initiate	Literally, a novice who has been through an initiation ceremony and has begun introductory instruction.
Apprentice	Literally, one who is learning – a student undergoing a program of instruction beyond the introductory level. Traditionally, the apprentice is immersed in the domain by living with and assisting someone at a higher level. The length of an apprenticeship depends on the domain, ranging from about one to 12 years in the Craft Guilds.
Journeyman	Literally, a person who can perform a day's labor unsupervised, although working under orders. An experienced and reliable worker, or one who has achieved a level of competence. Despite high levels of motivation, it is possible to remain at this proficiency level for life.
Expert	The distinguished or brilliant journeyman, highly regarded by peers, whose judgments are uncommonly accurate and reliable, whose performance shows consummate skill and economy of effort, and who can deal effectively with certain types of rare or "tough" cases. Also, an expert is one who has special skills or knowledge derived from extensive experience with subdomains.
Master	Traditionally, a master is any journeyman or expert who is also qualified to teach those at a lower level. Traditionally, a master is one of an elite group of experts whose judgments set the regulations, standards, or ideals. Also, a master can be that expert who is regarded by the other experts as being "the" expert, or the "real" expert, especially with regard to sub-domain knowledge.

takes to complete the moves is an indication of one's chess skill (Chi, 1978). Although this task is probably not sensitive enough to discriminate among the exceptional experts, a task such as this can be adapted as an index of expertise. In short, to identify a truly exceptional expert, one often resorts to some kind of measure of performance. The assessment of exceptional experts needs to be accurate since the goal is to understand their superior performance. Thus, this approach studies the remarkable few to understand how they are distinguished from the masses.

Though expertise can be studied in the context of "exceptional" individuals, there is a tacit assumption in the literature that perhaps these individuals somehow have greater minds in the sense that the "global qualities of their thinking" might be different (Minsky & Papert, 1974, p. 59). For example, they might utilize more powerful domain-general heuristics that novices are not aware of, or they may be naturally endowed with greater memory capacity (Pascual-Leone, 1970; Simonton, 1977). This line of reasoning is extended to cognitive functioning probably because genetic inheritance does seem to be a relevant component for expertise in music and sports. In short, the tacit assumption is that greatness or creativity arises from chance and unique innate talent (Simonton, 1977). Let's call this type of work in psychology the study of exceptional or *absolute* expertise.

A second research approach to expertise is to study experts in comparison to novices. This *relative* approach assumes that expertise is a level of proficiency that novices can achieve. Because of this assumption, the definition of expertise for this contrastive approach can be more relative, in the sense that the more knowledgeable group can be considered the "experts" and the less knowledgeable group the "novices." Thus the term "novices" is used here in a generic sense, in that it can refer to a range of nonexperts, from the naives to the journeymen (see Table 2.1 for definitions).

Proficiency level can be grossly assessed by measures such as academic qualifications (such as graduate students vs. undergraduates), seniority or years performing the task, or consensus among peers. It can also be assessed at a more fine-grained level, in terms of domain-specific knowledge or performance tests.

One advantage of this second approach, the study of "relative expertise," is that we can be a little less precise about how to define expertise since experts are defined as relative to novices on a continuum. In this relative approach, a goal is to understand how we can enable a less skilled or experienced persons to become more skilled since the assumption is that expertise can be attained by a majority of students. This goal has the advantage of illuminating our understanding of learning since presumably the more skilled person became expert-like from having acquired knowledge about a domain, that is, from learning and studying (Chi & Bassok, 1989) and from deliberate practice (Ericsson, Chapter 38; Ericsson, Kramepe, & Tesch-Romer, 1993; Weisberg, 1999). Thus, the goal of studying relative expertise is not merely to describe and identify the ways in which experts excel. Rather, the goal is to understand how experts became that way so that others can learn to become more skilled and knowledgeable.

Because our definition characterizes experts as being more knowledgeable than non-experts, such a definition entails several fundamental theoretical assumptions. First, it assumes that experts are people who have acquired more knowledge in a domain (Ericsson & Smith, 1991, Table 2.1) and that this knowledge is organized or structured (Bedard & Chi, 1992). Second, it assumes that the fundamental capacities and domain-general reasoning abilities of experts and non-experts are more or less identical. Third, this framework assumes that differences in the performance of experts and non-experts are determined by the differences in the way their knowledge is represented.

Manifestations of Experts' Skills and Shortcomings

Numerous behavioral manifestations of expertise have been identified in the research literature and discussed at some length (see edited volumes by Chi, Glaser, & Farr, 1988; Ericsson & Smith, 1991; Ericsson, 1996; Feltovich, Ford, & Hoffman, 1997; Hoffman, 1992). Most of the research has focused on how experts excel, either in an absolute context or in comparison to novices. However, it is equally important to understand how experts fail. Knowing both how they excel and how they fail will provide a more complete characterization of expertise. This section addresses both sets of characteristics.

Ways in which Experts Excel

I begin by very briefly highlighting seven major ways in which experts excel because this set of findings have been reviewed extensively in the literature, followed by a slightly more elaborate discussion of seven ways in which they fall short.

GENERATING THE BEST

Experts excel in generating the best solution, such as the best move in chess, even under time constraints (de Groot, 1965), or the best solution in solving problems, or the best design in a designing task. Moreover, they can do this faster and more accurately than non-experts (Klein, 1993).

DETECTION AND RECOGNITION

Experts can detect and see features that novices cannot. For example, they can see patterns and cue configurations in X-ray films that novices cannot (Lesgold et al., 1988). They can also perceive the "deep structure" of a problem or situation (Chi, Feltovich, & Glaser, 1981).

QUALITATIVE ANALYSES

Experts spend a relatively great deal of time analyzing a problem qualitatively, developing a problem representation by adding many domain-specific and general constraints to the problems in their domains of expertise (Simon & Simon, 1978; Voss, Greene, Post, & Penner, 1983).

MONITORING

Experts have more accurate self-monitoring skills in terms of their ability to detect errors and the status of their own comprehension. In the domain of physics, experts were more accurate than novices in judging the difficulty of a problem (Chi, Glaser, & Rees, 1982). In the domain of chess, expert (Class B) chess players were more accurate than novices in predicting the number of pieces they thought they could recall immediately or the number of times they thought they needed to view a chess position in order to recall the entire position correctly. Moreover, the experts were significantly more accurate in discriminating their ability to recall the randomized (positions with the pieces scrambled) from the meaningful chess positions, whereas novices thought they could recall equal number of pieces from the randomized as well as the meaningful positions (Chi, 1978).

STRATEGIES

Experts are more successful at choosing the appropriate strategies to use than novices. For example, in solving physics problems, the instructors tend to work forward, starting from the given state to the goal state, whereas students of physics tend to work backwards, from the unknown to the givens (Larkin, McDermott, Simon, & Simon, 1980). Similarly, when confronted with routine cases, expert clinicians diagnose with a data-driven (forward-working) approach by applying a small set of rules to the data; whereas less expert clinicians tend to use a hypothesis-driven (backward chaining) approach (Patel & Kaufman, 1995). Even though both more-expert and the less-expert groups can use both kinds of strategies, one group may use one kind more successfully than the other kind. Experts not only will know which strategy or procedure is better for a situation, but they also are more likely than novices to use strategies that have more frequently proved to be effective (Lemaire & Sielger, 1995).

OPPORTUNISTIC

Experts are more opportunistic than novices; they make use of whatever sources of information are available while solving problems (Gilhooly et al., 1997) and also exhibit more opportunism in using resources.

COGNITIVE EFFORT

Experts can retrieve relevant domain knowledge and strategies with minimal cognitive effort (Alexander, 2003, p. 3). They can also execute their skills with greater automaticity (Schneider, 1985) and are able to exert greater cognitive control over those aspects of performance where control is desirable (Ericsson, Chapter 13).

Ways in which Experts Fall Short

An equally important list might be ways in which experts do not excel (Sternberg, 1996; Sternberg & Frensch, 1992). Because much less has been written about experts' handicaps, I present a slightly more extensive discussion of seven ways in which experts do not surpass novices. This list also excludes limitations that are apparent in experts, but in fact novices would be subjected to the same limitations if they have the knowledge. For example, experts often cannot articulate their knowledge because much of their knowledge is tacit and their overt intuitions can be flawed. This creates a science of knowledge elicitation to collaboratively create a model of an expert's knowledge (Ford & Adams-Webber, 1992). However, this shortcoming is not listed below since novices would most likely have the same problem except that their limitation is less apparent since they have less knowledge to explicate.

DOMAIN-LIMITED

Expertise is domain-limited. Experts do not excel in recall for domains in which they have no expertise. For example, the chess master's recall of randomized chess board positions is much less accurate than the recall for actual positions from chess games (Gobet & Simon, 1996), and the engineer's attempt to recall the state of affairs of thermal-hydraulic processes that are not physically meaningful is much less successful than attempts to recall such states that are meaningfull (Vicente, 1992). There are a number of demonstrations from various other domains that show experts' superior recall compared to novices for representative situations but not for randomly rearranged versions of the same stimuli (Ericsson & Lehmann, 1996; Vicente & Wang, 1998). Thus, the superiority associated with their expertise is very much limited to a specific domain.

Of course there are exceptions. For example, expert chess players can display a reliable, but comparatively small, superiority of memory performance for randomized chess positions when they are briefly presented (see Gobet & Charness, Chapter 30), or when the random positions are presented at slower rates (Ericsson, Patel, & Kinstch, 2000). Nevertheless, in general, their expertise is domain-limited.

overly confident

Experts can also miscalibrate their capabilities by being overly confident. Chi (1978) found that the experts (as compared to both the novices and the intermediates) overestimated the number of chess pieces they could recall from coherent chess positions (see Figure 9, left panel, Chi, 1978). Similarly, physics and music experts overestimated their comprehension of a physics or music text, respectively, whereas novices were far more accurate (Glenberg & Epstein, 1987). It seems that experts can be overly confident in judgments related to their field of expertise (Oskamp, 1965). Of course, there are also domains, such as weather forecasting, for which experts can be cautious and conservative (Hoffman, Trafron, & Roebber 2005).

glossing over

Although experts surpass novices in understanding and remembering the deep structure of a problem, a situation, or a computer program, sometimes experts fail to recall the surface features and overlook details. For example, in recalling a text passage describing a baseball game, individuals with high baseball knowledge actually recalled fewer baseball-irrelevant sentences than individuals with low baseball knowledge (Voss, Vesonder, & Spilich, 1980), such as sentences containing information about the weather and the team. But high-knowledge individuals do recall information that is relevant to the goal structure of the game, as well as changes in the game states. Similarly, in answering questions about computer programs, novices are better than experts for concrete questions, whereas experts are better than novices for abstract questions (Adelson, 1984).

In medical domains, after the presentation of an endocarditic case, 4th and 6th year medical students recalled more propositions about the case than the internists (Schmidt & Boshuizen, 1993). Moreover, because the internists' biomedical knowledge was better consolidated with their clinical knowledge, resulting in "short cuts," their explanations thus made few references to basic pathophysiological processes such as inflammation. In short, it is as if experts gloss over details that are the less relevant features of a problem.

context-dependence within a domain

The first limitation of expertise stated above is that it is restricted to a specific domain. Moreover, within their domain of expertise, experts rely on contextual cues. For example, in a medical domain, experts seem to rely on the tacit enabling conditions of a situation for diagnosis (Feltovich & Barrows, 1984). The enabling conditions are background information such as age, sex, previous diseases, occupation, drug use, and so forth. These circumstances are not necessarily causally related to diseases, but physicians pick up and use such correlational knowledge from clinical practice. When expert physicians were presented the complaints associated with a case along with patient charts and pictures of the patients, they were 50% more accurate than the novices in their diagnoses, and they were able to reproduce a large amount of context information that was directly relevant to the patient's problem (Hobus, Schmidt, Boshuizen, & Patel, 1987). The implication is that without the contextual enabling information, expert physicians might be more limited in their ability to make an accurate diagnosis.

Experts' skills have been shown to be context-dependent in many other studies, such as the failure of experienced waiters to indicate the correct surface orientation of liquid in a tilted container, despite their experience in the context of wine glasses (Hecht & Proffitt, 1995), and the inaccuracies of wildland fire fighters in predicting the spread of bush fire when the wind and slope are opposing rather than congruent, which is an unusual situation (Lewandowsky, Dunn, Kirsner, & Randell, 1997).

INFLEXIBLE

Although Hatano and Inagaki (1986) have claimed that exceptional (versus routine) experts are adaptive, sometimes experts do have trouble adapting to changes in problems that have a deep structure that deviates from those that are "acceptable" in the domain. For example, Sternberg and Frensch (1992) found that expert bridge players suffered more than novice players when the game's bidding procedure was changed. Similarly, expert tax accountants had more difficulty than novice tax students in transferring knowledge from a tax case that disqualified a general tax principle (Marchant, Robinson, Anderson, & Schadewald, 1991). Perhaps the experts in these studies are routine experts; but they nevertheless showed less flexibility than the novices.

Inflexibility can be seen also in the use of strategies by Brazilian street vendors who can be considered "experts" in "street mathematics" (Schliemann & Carraher, 1993). When presented with a problem in a pricing context, such as "If 2 kg of rice cost 5 cruzeiros, how much do you have to pay for 3 kg?," they used mathematical strategies with 90% accuracies. However, when presented with a problem in a recipe context ("To make a cake with 2 cups of flour you need 5 spoonfuls of water; how many spoonfuls do you need for 3 cups of flour?"), they did not adapt their mathematical strategies. Instead, they used estimation strategies, resulting in only 20% accuracies.

INACCURATE PREDICTION, JUDGMENT, AND ADVICE

Another weakness of experts is that sometimes they are inaccurate in their prediction of novice performance. For example, one would expect experts to be able to extrapolate from their own task-specific knowledge how quickly or easily novices can accomplish a task. In general, the greater the expertise the worse off they were at predicting how quickly novices can perform a task, such as using a cell phone (Hinds, 1999). In tasks requiring decision under uncertainty, such as evaluating applicants for medical internships (Johnson, 1988) or predicting successes in graduate school (Dawes, 1971), it has been shown consistently that experts fail to make better judgments than novices. Such lack of superior decision making may be limited to domains that involve predicting human behavior, such as parole decisions, psychiatric judgment, and graduate school successes (Shanteau, 1984).

An alternative interpretation of experts' inaccuracies in making predictions is to postulate that they cannot take the perspectives of the novices accurately. Compatible with this interpretation is the finding that students are far more able to incorporate feedback from their peers than from their expert instructor in a writing task (Cho, 2004).

BIAS AND FUNCTIONAL FIXEDNESS

Bias is probably one of the most serious handicaps of experts, especially in the medical profession. Sometimes physicians are biased by the probable survival or mortality rates of a treatment. Christensen, Heckerling, Mackesy, Berstein, and Elstein (1991) found that residents were more susceptible to let the probable survival outcome determine options for treatment, whereas novice students were not. Fortunately, experienced physicians were not affected by the mortality rates either. In another study, however, my colleagues and I found the experienced physicians to manifest serious biases. We presented several types of cases to specialists, such as hematologists, cardiologists, and infectious disease specialists. Some were hematology cases and others were cardiology cases. We found that regardless of the type of specialized case, specialists tended to generate hypotheses that corresponded to their field of expertise: Cardiologists tended to generate more cardiology-type hypotheses, whether the case was one of a blood disease or an infectious disease (Hashem, Chi, & Friedman, 2003). This tendency to generate diagnoses about which they have more knowledge clearly can cause greater errors. Moreover, experts seem to be more susceptible to suggestions that can bias their choices than novices (Walther, Fieldler, & Nickel, 2003).

Greater domain knowledge can also be deleterious by creating mental set or functional fixedness. In a problem-solving context, there is some suggestion that the more knowledgeable participants exhibit more functional fixedness in that they have more difficulty coming up with creative solutions. For example, in a remote association task, three words are presented, such as *plate*, *broken*, and *rest*, and the subject's task is to come up with a fourth word that can form a familiar phrase with each of the three words, such as the word *home* for *home plate* (a baseball term), *broken home*, and *rest home*. A "misleading" set of three words can be *plate*, *broken*, and *shot*, in which the correct solution is *glass*. High baseball knowledge subjects were less able than low baseball knowledge subjects to generate correct solutions to the misleading type of problems because the first word *plate* primed their baseball knowledge so that it caused functional fixedness (Wiley, 1998).

In conclusion, the two sections above each summarized seven ways in which experts excel and seven ways in which they fall short. Although much more research has been carried out focusing on ways in which experts' greater knowledge allows them to excel, it is equally important to know ways in which their knowledge is limiting. The facilitations and limitations of knowledge can provide boundary conditions for shaping a theory of expertise.

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