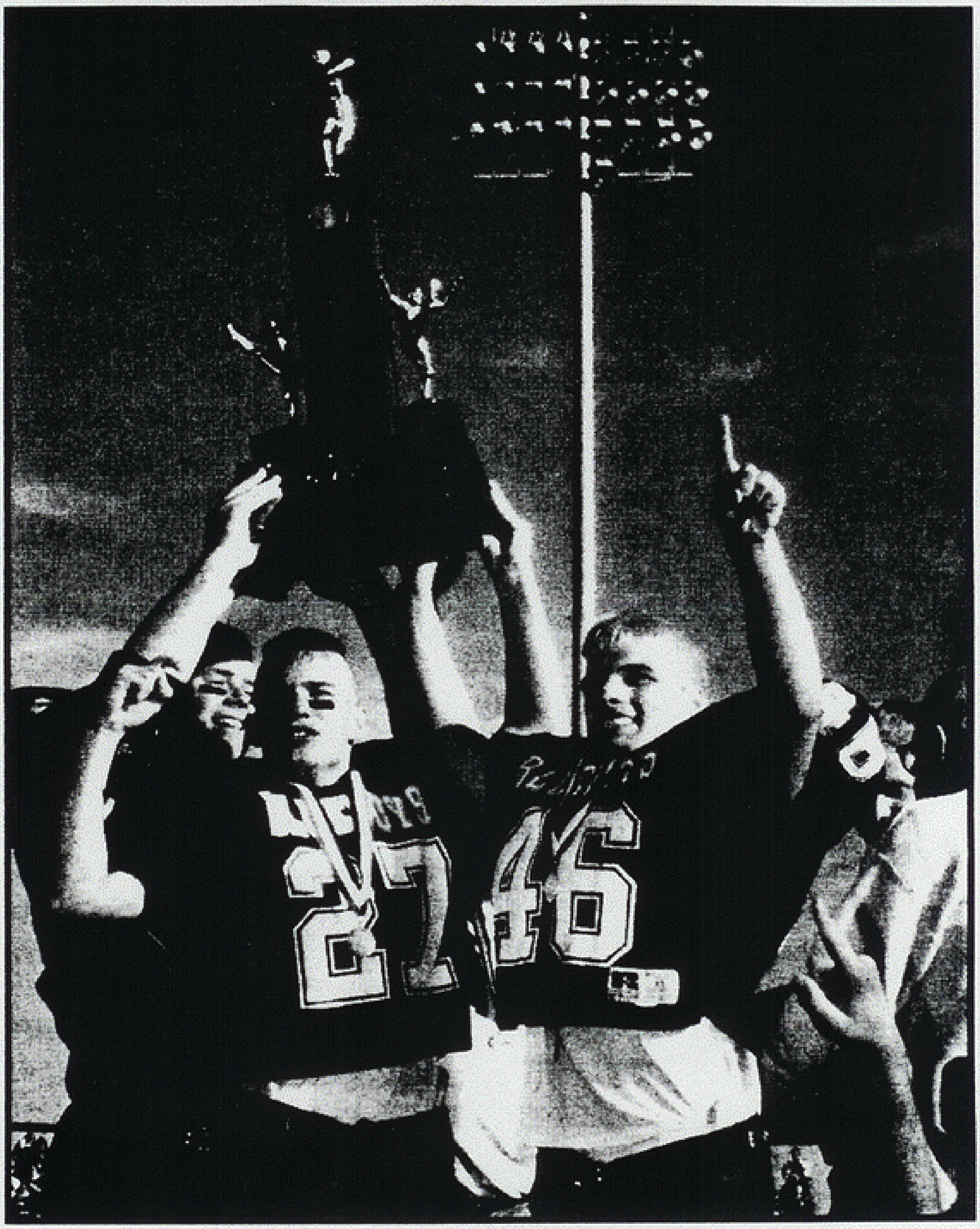
Chapter 2

Expert Performance in Sport

Current Perspectives and Critical Issues



Christopher M. Janelle
Charles H. Hillman

> False facts are highly injurious to the progress of science, for they often endure long; but false views, if supported by some evidence, do little harm, for every one takes a salutary pleasure in proving their falseness: and when this is done, one path towards error is closed and the road to truth is often at the same time opened.
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> —Charles Darwin, *The Descent of Man*, pp. 368-369

Though an avid hunter and occasional billiards player, Darwin likely did not place much emphasis on the development of sporting expertise when composing *On the Origin of Species* or *The Descent of Man*. However, the topic of expert sport performance has provided a fruitful battleground for the exchange of ideas and continued scientific advancement toward understanding the inherited and developed assets of superior athletes. On even casual consideration of the modern climate of athletic competition, it becomes readily obvious that Darwinian notions (survival of the fittest and species adaptation) are well represented in the microcosm of sport. In recent years, researchers have begun to unravel the mysteries of expertise. They have done so with increased attention on what it takes athletes to be the best, and they have done so despite (or maybe because of) diametrically opposed views that concern the development of superior achievement.

Expert athletes embody perhaps the most visible of all expert performers. They attract immense followings, enormous media attention, and the mutual admiration of coaches, fellow competitors, and teammates. This visibility is perhaps best exemplified by the fact that the most popular national and world events tend to surround sport competitions. The Olympic Games, the Super Bowl, Formula One racing events, the World Series of baseball, and World Cup soccer (among others) each provide examples of the massive popularity of sport and the immense opportunity to view expertise in action. However, despite being routinely observed, sport expertise is extremely difficult to characterize with a succinct list of requisite aptitudes. As such, the factors that predispose, describe, and lead to the emergence of the fittest athletes (in the Darwinian sense) remain largely unspecified, especially from a scientific standpoint.

Accounting for the qualities of the expert athlete necessitates a perspective that encompasses the inherent nature of sport as being diverse in task requirements and proficiencies. For example, to identify the common characteristics of expertise between an NFL quarterback and one of his offensive linemen could prove as futile as delineating the shared qualities of expertise between that offensive lineman and the conductor of the Boston Pops. In this chapter, we acknowledge such limitations, so we therefore identify and expound the generalizations made about experts in a variety of domains. We then present a discussion on the current state of theoretical development both in the general study of expertise as well as sport. Afterward, we examine sport-specific findings from several studies of expertise that were completed via a variety of tasks and simulations, and we also provide a synthesis of the existing expertise literature. Last, we make recommendations for specific research directions, which will provide systematic advancement in theory as well as applications for the selection and training of athletes.

Introduction to the Domains of Sport Expertise

Expert performance in sport can be defined as the consistent superior athletic performance over an extended period (Starkes, 1993). To obtain expert status, athletes must excel in no less than four domains: physiological, technical, cognitive (tactical/strategic; perceptual/decision-making), and emotional (regulation/coping; pyschological).

Expert Physiology

Physiological components of expertise include factors such as anaerobic power and aerobic capacity, muscle fiber type and distribution, body morphology and body segment size, height, flexibility, and general aesthetics (Wilmore & Costill, 1999). The physiological aspect of performance is unique to sport, whereas in other domains, it is typically of no concern. Physiological superiority has no real relevance in other expertise settings such as chess, music, electronics, mathematics, and computer programming. Likewise, the specific physiological necessities for expert achievement in various sports are as wide and varied as the sports themselves, and the distinctions can even be found among sports that require similar skill. For example, the physiological requirements for expertise in sprinting are quite different than those needed in a related movement pattern such as distance running.

Ample evidence exists to suggest that factors such as body morphology and muscle fiber type are malleable through extended practice and systematic training (e.g., Wilmore & Costill, 1999). However, sport and exercise physiologists agree that the degree of adaptability is indeed restricted and that the limits imposed are primarily genetically determined (e.g., Bouchard, Dionne, Simoneau, & Boulay, 1992; Bouchard, Malina, & Pérusse, 1997; Klissouras, 1997; Swallow, Garland, Carter, Zhan, & Sieck, 1998). As such, hereditary predispositions to physiological characteristics appear to be significant limiting factors to the overall level of expertise that may be acquired in sport. Although the research acknowledges the heritability of advantageous predispositions for certain sports, empirical documentation regarding the role of heredity as related to expertise is limited (e.g., Reilly, Bangsbo, & Franks, 2000). Given that this chapter is psychologically oriented, we will not give any additional attention to expert physiology, aside from a discussion of how it relates to other domains of expertise.

Technical Expertise

Technical expertise refers to the degree of sensorimotor coordination from which refined, efficient, and effective movement patterns emerge. Technical measures of technique and sport-skills tests include quantitative analysis, which includes assessment of the kinematics and kinetics of movement patterns. Qualitative indexes of technical expertise, such as artistic impression and aesthetic value, can be evaluated as well. In several sports, the technical aspects of the skill dictate the overall level of expertise, such as in gymnastics and figure skating, while in others they merely contribute to the overall quality of the movement.

Regarding the development of technical expertise, ample evidence exists to suggest that coordinated, refined, and efficient movement patterns emerge largely as a function of years of extended and systematic training, or deliberate practice (e.g., Ericsson & Lehman, 1996; Helsen Starkes, & Hodges, 1998; Starkes, 1993, 2000; Starkes, Deakin, Allard, Hodges, & Hayes, 1996). Over time, learners acquire skilled movement patterns that are less errant and more efficient, and the movements are performed with a high level of automaticity (e.g., Fitts & Posner, 1967; Logan, 1988; Schneider & Shiffrin, 1977; Singer, 2001).

Cognitive Expertise

Cognitive expertise can be broken down into two subdomains: tactical skills and decision-making abilities. The former comprises an athlete's global approach to a particular sport; the latter focuses more on an athlete's ability to make in-the-moment decisions.

Tactical and Strategic Knowledge

Tactical expertise is requisite for expert performance in virtually all achievement domains. Sport is unique, however, in that tactical knowledge involves not only the ability to determine what strategy is most appropriate in a given situation, but also whether the strategy can be successfully executed within the constraints of the required movements (e.g., McPherson, 1994; Starkes, 1993). Thus, tactical expertise in sport is quite different than nonmotor performance domains in that physiological and technical limitations constrain the strategic options available to sport performers.

Emanating from cognitive frameworks of information processing, the primary research methods employed to determine tactical expertise have been verbal protocol analysis and behavioral observation in practice and competitive sport settings (French & McPherson, 1999; French, Spurgeon, & Nevett, 1995; McPherson, 1993, 1994, 1999; McPherson & French, 1991). Through the collective study of the characteristics of expert memory, researchers have gleaned much information about the mechanisms of expert working memory, both short term and long term, as well as the organization of relevant domain-specific knowledge and retrieval processes.

Perceptual and Decision-Making Skill

Regardless of whether one is involved in self-paced or externally paced sport skills, expert athletes are capable of attending to and extracting the most relevant cues in the sport environment and can avoid attending to distracting or irrelevant cues. Perceptual skills include pattern recognition, the use and extraction of anticipatory cues, visual search strategies, and signal detection. Decision-making speed and accuracy is then based largely on the interpretive value of information acquired through perceptual skills and its appropriateness for effective response selection. Given the spectrum of literature in the mainstream sport expertise area, this domain has garnered the lion's share of research to date. Consequently, researchers can make several conclusions from this aggregate body of research with a significant degree of confidence. As will be presented later, the majority of research efforts in the perceptual and decision-making domain have indicated reliable differences between expert and nonexpert performers.

Emotional Expertise

Emotional expertise is divided into two arenas: emotional regulation and psychological skills. Emotional regulation involves exactly what it implies: an athlete's ability to monitor and exert some control over emotion. Psychological skills, however, include a broader range of factors, all of which may influence emotional readiness.

Emotional Regulation and Coping Strategies

When considering the sport context, even over the course of a single competition, one soon realizes that the gamut of possible emotions can be typically exhausted—from the elation and joy after a big play to the sadness, disappointment, and embarrassment that follow a poor performance. Emotions, and the capability to regulate them effectively, arguably account for a large portion of the variance in athletic performance. Despite the intuitive observation that sport is inherently emotional, a scientific understanding of the emotions of sport experts is virtually nonexistent. Studies of affective characteristics among elite performers tend to be largely descriptive and susceptible to self-report confounds. In addition, they typically do not involve comparisons to nonexpert samples. Needless to say, this domain of expertise warrants extensive future research.

Psychological Skills

In addition to acquiring the requisite skills as described in the aforementioned domains of expertise, the development of psychological skills is critical to expert performance. Psychological skills refer to performance-related determinants of expertise that include attributes such as motivation and goal-setting strategies; confidence-building and maintenance of a positive attitude; imagery and mental training; coachability considerations; and interpersonal skills. Relative to the large body of work that has been done on strategic and perceptual/decision-making aspects of expertise, few studies of these social-cognitive determinants of expert performance have been conducted, especially ones that compare experts and novices. In fact, rarely are these terms even mentioned in the reviews of expertise literature, aside from the references to the lack of research that describe how experts develop such skills.

Interactive Determinants of Expertise

When considering the various domains of expertise that must be achieved by today's elite athlete, one realizes that any weakness in one of them will significantly impede the athlete's capability to perform at the highest level. Expertise in one domain, however, can either facilitate or hinder the attainment of expertise in others. For example, social-cognitive factors such as motivation may largely influence the expression of the physiological characteristics deemed necessary for success in sport. That is, athletes who are highly motivated are more inclined to direct their efforts to the systematic physical training programs that will influence their physical and psychomotor capabilities. Likewise, the athletes' development of cognitive-behavioral skills enable them to achieve optimal performance. For instance, self-regulation through exposure to competitive challenges enables elite athletes to regulate emotional function and metacognitive strategies Such skills also may be genetically influenced. Figure 2.1 represent a schematic representation that depicts the interactive nature of th domains of expertise.

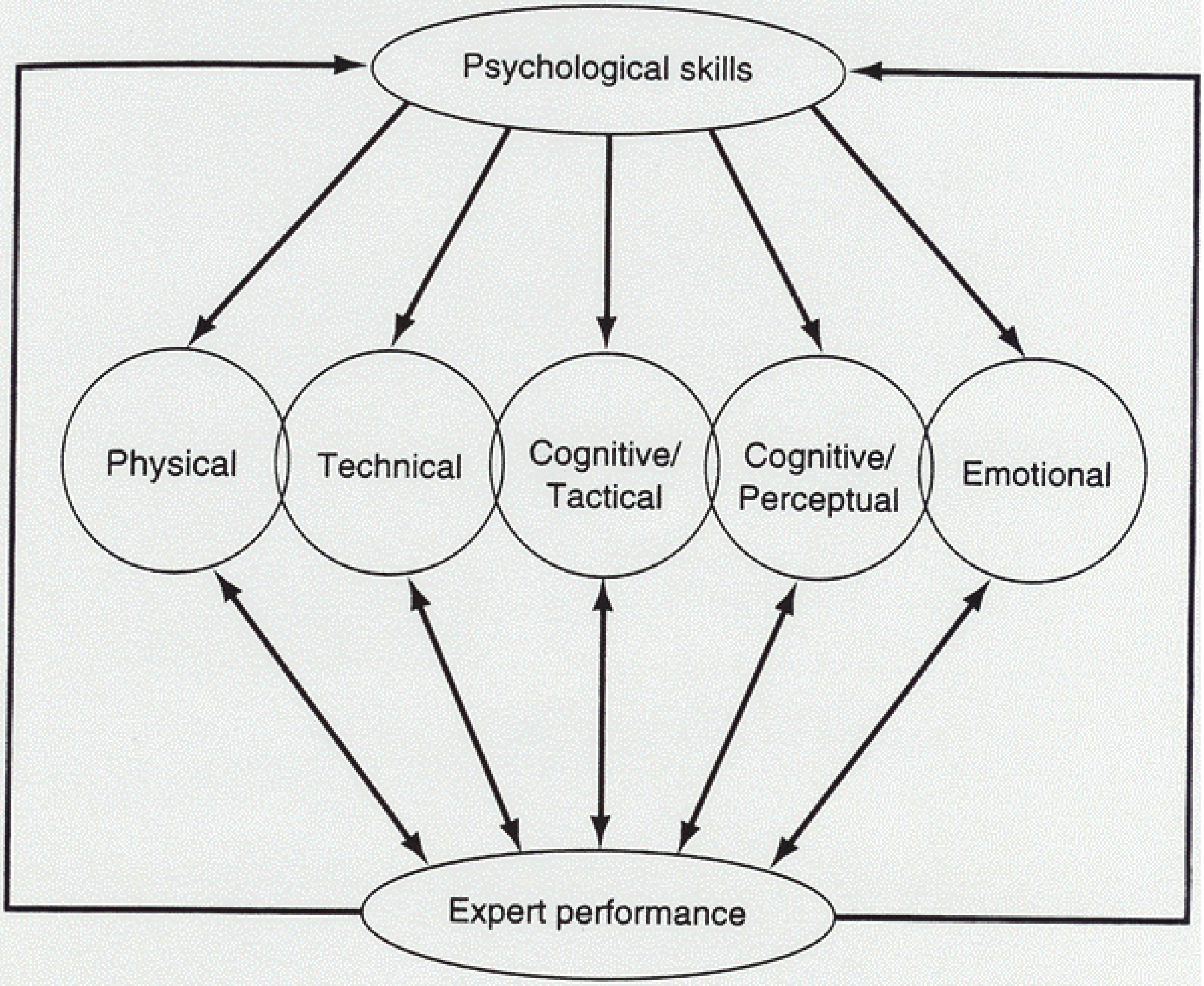

Figure 2.1 The domains of expertise in sport. Psychological skills influence the athlete's capability to perform components of each domain, with proficiencies in each domain interacting to dictate the overall level of sport expertise. The athlete's relative level of expertise suggests future alterations in psychological skill and preparation for sport participation, as well as specific improvements in each expertise domain.

Athletes associated with sport may find these introductory remarks intuitively obvious. As will become increasingly clear, however, the scientific study of sport expertise to date has been largely restrictive in attempts to describe and account for expertise phenomena. More specifically, the interactive effects of the components of sporting expertise have been neglected in favor of focusing on detached, independent, and solitary determinants of expertise, often in contrived settings. Similarly, mechanistic explanations of why and how these phenomena occur remain underdeveloped. Given the relatively recent emergence of expertise as a topic of scientific inquiry and its roots in cognitive psychology, the narrow scope of expertise research to date is understandable. However, the absence of a viable and inclusive theory to truly advance expertise research in a systematic manner has been prohibitive in this regard. In spite of this realization, researchers have made admirable efforts to provide a conceptual framework for the study of expertise, with an eye toward theory development and advancement of science in this intriguing area of study.

The Scientific Study of Experts

One might contend that arriving at a consensus among researchers, or at least a partial agreement on the nature of expertise, is not worth pursuing scientifically (Sternberg, 1996, 1998). Given the negative connotations that typically confront sport science scholars, the scientific study of sport expertise may be regarded with even less fanfare. However, our position is that the continued pursuit of knowledge regarding expertise is important for several philosophical, theoretical, practical, and ethical reasons. Perceptions of accomplishment, failure, and success are some of the most salient pieces of information on which people rely for a sense of self-worth, and such information is significantly shaped by the degree to which individuals perceive that they control their own destiny. Likewise, how and to whom training is structured may depend greatly on the existence of varying levels of perceived talent, work ethic, motivation, and cognitive or motor deficits (Detterman, Gabriel, & Ruthsatz, 1998).

Theoretical Foundations for the Study of Expertise

In explaining how experts in sport and other domains are capable of performing with remarkable levels of consistency and quality in their movements, theorists have attempted to describe the means by which expertise is achieved. They have attempted to do so primarily through orientations that would favor either a predominantly genetic perspective (talent and nature) or an environmental perspective (practice and nurture). At one end of the continuum, innate giftedness and talent would completely account for expert performance. The alternative viewpoint purports that expertise arises from (and is limited by) the accumulated duration of systematic training, regardless of any hereditary giftedness. Less restrictive than the former views is the notion that expertise arises as a consequence of some combination of both variables; that is, athletes arrive at expertise via both genetic and envi-ronmental interactions.

Considering contemporary literature, one would appear simplisti to attribute all variability in levels of expertise to innate talent. As would be expected, virtually no one adheres to this notion (Sternberg 1998). Appearing equally radical is the suggestion that the opposite end of the continuum is exclusively the most viable theoretical accoun for the acquisition of expertise. Despite its counterintuitive nature, the latter alternative has been strongly advanced by prominent research-ers (for a recent review, see Howe, Davidson, & Sloboda, 1998). At the crux of this approach is the notion that expertise is obtainable by virtu-ally anyone and that expert performance, irrespective of innate "tal-ent," will inevitably emerge through an extended period of "deliberate practice," typically either 10 years or 10,000 hours (Ericsson, Krampe & Tesch-Römer, 1993).

The greatest opposition to this extreme "nurturist" perspective (and admittedly not on the opposite end of the continuum) has been pre-sented by those who acknowledge the role of deliberate practice (or systematic training) and other environmental influences in achieving expertise; however, they recommend that innate hereditary factors impose influences on and limits to the level of acquirable expertise. This approach might best be described as an "interactionist" approach. Thus, recognizing that the strict "naturist" perspective has been all but abandoned, it appears that there are currently two prominent views that explain expertise, with each acknowledging the substantial role of practice.

The Common Denominator: Practice

Emerging from the "expertise approach" to determining what differ-entiates expert and nonexpert performers in their respective domains of excellence, a convincing corpus of evidence has been gathered to suggest that regardless of innate talent, hereditary predispositions, and genetic limitations, high levels of skill cannot be acquired without years of dedicated practice. Expert athletes progress toward excel-lence in much the same way as expert musicians (e.g., Lehmann, 1997; Sloboda & Howe, 1991), chess players (Charness, 1992; Charness, Krampe, & Mayr, 1996; Gobet & Simon, 1996, 1998), and scholars (cf. Simonton, 1999, 2000). Evidence suggests that experts adhere to a strict regimen of extended practice that is not necessarily coach developed. Such practice is characterized by structured activities that require ef-fort and concentration, that do not immediately lead to financial or other extrinsic rewards, and that are not inherently enjoyable (Ericsson, Krampe, & Tesch-Römer, 1993; Starkes, 2000; Starkes, Helsen, & Jack, 2001). These general characteristics of deliberate practice have minor exceptions to their basic tenets, most notably that many components of deliberate practice are deemed by athletes as enjoyable (cf. Hodges & Starkes, 1996). However, the majority of findings have indicated that elite athletes in a variety of sport activities do practice, and they deliberately practice, more so than their relative nonexpert counterparts. As such, the importance of deliberate practice, as outlined by Ericsson and colleagues (1993), is generally agreed on.

Most would agree that although compelling and accurate, the finding that "those who practice more get better" is somewhat obvious. Driving this concern is the fact that knowing how much to practice really tells one very little about why people get better at what they do. What comes to mind is a phrase still popular among coaches and teachers, "practice makes perfect." The more recent adage, "perfect practice makes perfect," carries with it the underlying assumption that practicing incorrectly, or going through the motions, does not lead to gains in achievement. The notions of deliberate practice certainly capture the general idea that practice must be conducted structurally, systematically, and done effortfully and often. However, meaningful advances in expertise research must move beyond evaluation of how much practice is necessary and must move forward to understanding the *what* and the *how* of practice (e.g., Davids, 2000; Durand-Bush & Salmela, 2001; Singer & Janelle, 1999; Starkes, 1993; 2001). In other words, researchers need to be able to provide practical, real-world recommendations to aspiring expert athletes.

The Expertise Approach

As popularized by Ericsson and Smith (1991) and adapted and structured from the landmark work of Chase and Simon (1973a, 1973b) with chess experts, the expertise approach has been the primary driving force behind much of the research conducted in the area of expertise over the past two decades. Ericsson and Smith argue that the scientific identification of expert characteristics could be accomplished through a three-step process. The first step is for researchers to identify reproducible and superior task performances in the laboratory setting using representative tasks. Second, they must compile an index of data that reflect the cognitive processes that underlie superior performance and allow it to occur. During this second step, researchers may have to manipulate the environmental conditions under which expert performance is maintained so that they may identify critical differences as a result of task variations. As such, they may be able to uncover the mechanisms that govern and regulate experts' ability to demonstrate consistent high achievement. During the third step, the researchers provide explanations to account for how the mechanisms identified in the second step were acquired. By following this three-step process, it was implied that researchers could advance "toward a general theory of expertise" (Ericsson & Smith, 1991).

The expertise approach is favored by Ericsson and Smith (1991) when compared with other plausible methods for the investigation of outstanding performance (see table 2.1). On examination of table 2.1, however, we should point out the notable absence of "the primarily inherited and acquired" category, which thereby neglects a potentially viable alternative account for expertise. As such, the expertise approach has been criticized as being biased toward the detection and description of environmental influences on expert performance (e.g., Heller & Ziegler, 1998; Rowe, 1998).

Table 2.1
Different Approaches to Accounting for Outstanding Performance

Attribution	Construct	Research approach
Primarily inherited General abilities	Intelligence, personality	Correlation with personality profile, general intelligence
Specific abilities	Musical ability, artistic ability, bodybuilding	Correlation with measures of specific ability
Primarily acquired General learning and experience	General knowledge and cognitive strategies	Investigation of common processing strategies
Domain-specific training and practice	Domain- or task-specific knowledge	Analysis of task performance, that is the expertise approach

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By favoring the expertise approach, researchers must recognize that the skills identified as task-specific and acquired are inherently the product of genetic and environmental interactions, which are undoubtedly embodied in any sample of experts. Acknowledging a genetic component, even among what appear to be clearly environmental influences on expert performance, the expertise approach has been invaluable in guiding the identification of expert characteristics in a variety of domains, not the least of which has been sport.

Sport-Specific Expertise As Developed Through Practice

With slight departures from Ericsson and Smith (1991), the expertise approach in its many forms has served as a source of guidance for the current literature that has been conducted to clarify the nature of expert performance and skill acquisition in sport. With few exceptions, expert-novice differences have been consistently identified in a number of skills and abilities. Findings from these areas are briefly summarized as follows.

Pattern Recognition, Memory, and Tactical Skills

The topic of memory has been the centerpiece of much of the expertise research to date. In chess, for example, domain-specific expert memory has consistently been shown to be superior to that of relative nonexperts, and the expert advantage is especially pronounced in structured situations. These findings have been replicated in a variety of sport domains, specifically when expert athletes have been confronted with structured game situations and plays. In sports as diverse as baseball (McPherson, 1993), volleyball (Allard & Starkes, 1980), soccer (Helsen & Pauwels, 1993; Williams, Davids, Burwitz, & Williams, 1993), and figure skating (Deakin, 1987; Deakin & Allard, 1992), athletes have demonstrated reliable advantages in recognition, recall, and retention in comparison to relatively nonexpert counterparts. Likewise, their attainment of an expert advantage in these types of tasks appears to be due to direct and repeated training in the task environment; that is, it is not acquirable solely from observational learning of the specific event (Allard, Deakin, Parker, & Rodgers, 1993; Williams & Davids, 1995).

Regarding the tactical or strategic requirements for expertise in sport, the work of McPherson (1993, 1994, 1999, 2000) and the work of French and colleagues (French, Spurgeon, & Nevett, 1995; French & Thomas, 1987) have largely confirmed the existence of an extensive declarative and procedural knowledge base. From this base, expert athletes are capable of extracting the most appropriate responses to meet specific environmental demands. It is a repertoire of facts and procedures from which expert athletes form tactical strategies and therefore increase the effectiveness of their decision making. Additionally, this knowledge base appears to be acquired over a substantial period of deliberate practice.

Knowing "what to do" and "how to do it" reflects the specific and unique demands of sport. The development of response execution and coordination proficiencies is critical in sport settings but is minimally important in other activities, such as chess. As such, the capability to execute a skill influences the tendency to rely on the skill as a tactical option in game situations. French et al. (1996) demonstrated that youth baseball participants will not choose an action as a response possibility when a particular skill cannot be physically executed. The implications of this finding cannot be overestimated when one considers the unique nature of sport expertise. The particular constraints imposed on developing experts are not completely attributable to psychomotor or cognitive input, but instead, they are limited by developmental, technical, and physiological factors.

Anticipatory Behaviors and Visual Search Strategies

Another primary area of interest to sport psychology researchers is the identification of expert-novice differences in the use and extraction of pertinent information for the purpose of anticipation. Researchers have used an array of methods to determine what information experts attend to and how they process it in advance so that they can execute the apparently effortless responses in situations that demand high precision, under restrictive time constraints and uncertain stimulus properties. Of these methods, the most popular have been occlusion paradigms, eye-movement registration techniques, and the manipulation of mental chronometry through the use of cost-benefit paradigms.

Early research by Abernethy and colleagues (e.g., Abernethy & Russell, 1987a, 1987b) examined how temporal and spatial occlusion of various cues affected the anticipation abilities of expert and novice badminton players. Temporal occlusion techniques indicated that expert players were more capable of using information presented earlier in the visual display than were novices. These studies also demonstrated that prediction accuracy was adversely affected for experts when critical aspects of the scene were spatially occluded, an effect not noticed for novices. Presumably, novices were less attuned to arm and racket orientations, which would have granted them prediction information. These findings were replicated with squash players (Abernethy, 1990). The pioneering work of Abernethy and colleagues, as well as earlier attempts (Isaacs & Finch, 1983; C.M. Jones & Miles, 1978), provided the foundation for further work in this area and highlighted the superior cue-extraction and utilization capabilities of expert performers in reactive settings.

Regarding eye-tracking studies, the results obtained are generally consistent with occlusion findings, despite occasional assertions to the contrary (e.g., Abernethy, 1990). The studies indicate a superior attunement to critical environmental cues among expert performers, as implied from their search patterns. Within the broad range of sport applications in which eye movements have been recorded, reliable differences have been identified between expert and novice athletes in both self-paced and externally paced tasks in fixation location, fixation duration, search order, and search rate. Generally, experts consistently demonstrate more efficient search strategies in laboratory simulations and real-world applications of eye-movement recordings. They fixate longer and more often on the most relevant cues in a given display, and they exhibit fixation patterns that maximize the capability to extract information from peripheral visual sources. These differences have emerged in a number of reactive sports (e.g., Goulet, Bard, & Fleury, 1989; Helsen & Pauwels, 1990, 1993; Ripoll & Fleurance, 1985; Shank & Haywood, 1987; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996; Singer et al., 1998; Williams, Davids, Burwitz, & Williams, 1994). If one assumes a high degree of coupling between fixation location and cue utilization, then experts appear to be capable of extracting information from foveal and ambient visual fields to respond quickly and appropriately.

Expert-novice differences in search patterns have been identified and documented in self-paced tasks as well. Perhaps the first study to demonstrate these differences was published by Vickers (1992) who documented expertise differences in the performance of the golf putt. Later research focused on the "quiet eye period," a duration of time needed for accurate programming of motor responses. The quiet eye period takes place between the last fixation of a target and the initiation of the motor response (Vickers, 1996a). Reliable expert-novice differences in quiet eye period have been revealed in an increasing number of sports, such as basketball free-throw shooting (Vickers, 1996a, 1996b), small bore rifle shooting (Janelle et al., 2000; Janelle, Hillman, & Hatfield, 2000), and biathlon (Vickers, Williams, Rodrigues, Hillis, & Coyne, 1999). The consistent finding is that experts maintain a longer quiet eye period before the initiation of movement.

Recently, researchers have looked toward multimethod assessment of attentional allocation, perceptual processing, and information extraction. Efforts have therefore been made to determine whether occlusion paradigms, verbal report, and eye-tracking indexes mutually correspond. For example, Williams and Davids (1997, 1998) have studied the eye movements of expert and novice soccer players as compared to verbal report and occlusion data in 1-on-1, 3-on-3, and 11-on-11 soccer situations. Though largely congruent, the researchers noticed that eye-movement indexes of the most important information-gathering areas of the display were different than those that appeared more informative using occlusion techniques. Likewise, verbal reports were occasionally decoupled from eye-movement indications of attentional allocation. These differences were more pronounced for expert soccer players than for relative nonexperts. Therefore, researchers may benefit significantly by comprehensively describing expert attentional processing through the involvement of multiple assessment modes of data collection.

In addition to using eye-tracking systems and occlusion paradigms to infer attentional allocation, researchers can evaluate the orienting of attention and the potential costs and benefits through anticipation via the manipulation of expectations and conditional probabilities. A person's capability to switch attention from one source of information to another, in spite of preconceived probabilities and attentional biases, defines the "attentionally flexible" performer (Nougier & Rossi, 1999). Through variations of the classic cost-benefit paradigm (Posner, 1980), an expert advantage with regard to attentional flexibility has been documented (e.g., Nougier, Azemar, Stein, & Ripoll, 1992; Nougier, Ripoll, & Stein, 1989; Nougier & Rossi, 1999; Rossi & Zani, 1991; Tenenbaum, Stewart, & Sheath, 1999; Zani & Rossi, 1990). Experts are more resilient to incorrect a priori expectations and can therefore override dysfunctional automatic orienting processes more efficiently than can nonexperts.

In addition to the typical reaction time measures that are employed in this line of research, researchers can record event-related cortical potentials (ERPs) as an index of attentional processing. Intriguing work by Rossi and Zani (1991; Zani & Rossi, 1990) has demonstrated the specificity of expertise by showing that experts and novices process the same environmental stimuli differently. They compared expert trap shooters with expert skeet shooters. Trap shooting is a sport in which the stimulus characteristics are unpredictable, and skeet shooting has stimulus characteristics that are much more predictable. The two types of shooters differentially processed auditory signals in line with the domain-specific training to which they had been exposed in their particular sports. More specifically, trap shooters allocated increased attentional resources to the earlier, stimulus-driven stages of processing whereas skeet shooters used a more memory-driven mode of processing. Other ERP studies have demonstrated reliable differences between experts and relative novices in volleyball (Pesce Anzeneder & Bosel, in press) and in baseball (Radlo, Janelle, Barba, & Frehlich, 2001). These findings suggest a comparative ease by which experts are capable of minimizing attentional/anticipatory costs and thus maximizing benefits so as to improve performance. Psychophysiological performance profiling has been an increasing focus of several other research areas, and it is discussed in the next section.

The Psychophysiology of Expert Performance

During the past two decades, electroencephalography (EEG), as well as other psychophysiological measures (e.g., heart rate), have been used to identify differences between experts and novices during sport performance (for a recent review, see Hatfield & Hillman, 2001). The essential contributions of this work have been in the descriptive identification of the psychophysiological correlates of experts in sport and the comparative differences with those at lesser skill levels. A distinct advantage of the psychophysiological approach to understanding expertise lies in its capability to evaluate ongoing aspects of cognition, attention, and emotion in real time.

Much of the research that has examined skill-based differences in sport has come from the psychophysiological study of marksmen. From a psychophysiological perspective, marksmen provide an ideal sample in which to study expertise. Real-time data can be covertly collected in the absence of bioelectrical signal artifact as a result of movement, which typically prohibits this sort of data collection in other sports. Further, because these experts are highly attentive and visually focused during performance, they provide insight into the associated cortical mechanisms involved in this type of expertise behavior.

Initially, intrasubject hemispheric EEG differences were observed in elite marksmen during the preparatory period before shot execution (Hatfield, Landers, & Ray, 1984). Observed differences indicated that elite marksmen progressively relaxed the left hemisphere of their cortex before shot execution as measured by increased alpha power, which has been associated with one's verbal-analytic processes. The effect was not observed in the right hemisphere, which has been associated with one's visual-spatial processes. These two findings strongly suggest that these processes are germane to superior performance in marksmanship. This asymmetric pattern of alpha power observed during performance has been found to be quite robust, and it has been replicated in numerous other studies with marksmen (e.g., Hillman, Apparies, Janelle, & Hatfield, 2000;

Janelle et al., 2000) as well as in other sports (Crews & Landers, 1993; Landers et al., 1994).

In comparison with elite marksmen, research has also incorporated those with lesser skill levels to better understand underlying differences that accompany skill acquisition (Haufler, Spalding, Santa-Maria, & Hatfield, 2000; Janelle et al., 2000; Landers et al., 1994). Although these studies have utilized participants at various skill levels, researchers have arrived at consistent findings. Specifically, asymmetric EEG differences between the two cerebral hemispheres have not been observed to the same degree that is exhibited in elite marksmen, even after lesser skilled subjects have been trained for some period (Janelle et al., 2000; Landers et al., 1994). Interpretation of differences in hemispheric alpha asymmetry between elite and lesser skilled marksmen can be accounted for by two related phenomena: one, the efficient allocation of relevant neural resources that accompany expertise, and two, decreased performance states. As such, expertise in marksmanship is not only accompanied by the relative increased allocation of relevant neural resources (the right hemisphere), but also by the quieting of irrelevant resources (the left hemisphere).

Extending the concept of neural resource allocation during skilled performance, Hillman and his colleagues (2000) found intraexpert differences in alpha power during shot execution and rejection. Specifically, expert marksmen showed global increases in alpha power before their decision to reject a shot (when they pull away from the target without firing a shot) compared to the time just before shot execution. This finding suggests that a certain degree of relaxation (alpha power) is necessary during performance; after which, too much cortical relaxation may relate to performance decrements. Further, alpha power was found to increase progressively to the point of rejection, a finding not observed during shot execution. These data again speak to the adaptive nature of neural resource allocation during sport performance. Global increases in alpha power appear to relate to an inability to gather or utilize the necessary resources to accomplish the given task successfully. Interestingly, it appears as though in this case, the inefficient allocation of resources was recognized on a subjective level, which allowed the marksmen to reject the shot and begin the aiming period over again while trying to orchestrate a more successful mental set.

Recently, attention has been paid toward examining the relatedness of various cortical regions (EEG coherence) during marksmanship performance, with the assumption that increased relatedness reflects lesser skill levels. In terms of neural resource allocation, a greater amount of relatedness between two regions indicates decreased functional autonomy between those regions. Hence, the allocation of resources may be described as less efficient. Deeny, Hillman, Janelle, and Hatfield (2001) examined elite and lesser skilled marksmen with the a priori prediction that elite marksmen would show decreased cortical relatedness. Results supported the hypothesis and suggested that elite marksmen compared to lesser skilled marksmen exhibited increased psychomotor efficiency in terms of neural resource allocation. While these findings cannot be directly linked to behavioral performance (the marksmen's score), they are descriptive of differential cortical activation between elite and lesser skilled performers.

Sport scientists have also studied cortical ERPs during the period immediately preceding shooting tasks. Specifically, Konttinen and Lyytinen (1992) measured slow potential (SP) negativity (cortical activation related to stimulus processing) in national level marksmen. Results showed that increased negativity was found before the trigger pull and that less accurate shots were associated with even greater negativity. This finding suggests that the level of arousal preceding the poorer shots may have been excessive whereas a more efficient profile of cortical activation was associated with superior performance. Other work by Konttinen and Lyytinen (1993) and colleagues (Konttinen, Lyytinen, & Era, 1999) has supported their initial findings by demonstrating that intra–marksmen variability between superior and poorer shots exists in SP negativity. As a result, this variability affects performance. Further, Konttinen et al. (1999) compared elite Finnish Olympic team marksmen with nationally ranked shooters who did not have international competitive experience. They found increased SP positivity for poorer shots versus superior shots, which suggested that the positivity reflected the shooters' increased effort to inhibit irrelevant motor activity and thus override the SP negativity associated with arousal regulation. In other words, researchers observed a less efficient cortical profile during poorer performance. It is interesting that differences in cortical SP profiling associated with performance emerged in light of the slight differences in skill level between the two groups.

Anxiety, Emotion, and Expert Performance

Despite the inherent realization that anxiety and other affective states dramatically influence performance effectiveness, the exploration of expert-novice differences in this regard is in its infancy. Intuitively, it would appear that because experts are more capable of demonstrating superior performance than novices, they must be capable of dealing with affective states more appropriately than novices. However, at least two alternative explanations are viable for how experts and nonexperts respond to situational influences on performance. One, experts do not experience the degree of emotional activation that novices do; two, experts are capable of regulating emotional fluctuations with compensatory mechanisms to allow the maintenance of high-performance levels. Although empirical evidence is scarce, we will briefly describe and evaluate the relative contribution of each of these explanations (and potential others).

Predominant findings from descriptive studies of expert athletes indicate that the elite athlete tends to possess an elevated, vigorous mood state (e.g., Terry, 1995). However, despite findings that athletes are characterized by more positive mood states relative to nonathletic populations, the majority of extant research indicates that mood profiles are not effective in differentiating relative expertise levels (e.g., Terry, 1995). Recent research has applied the Individual Zones of Optimal Functioning (IZOF) model to study affective influences on performance, and it has been more fruitful in accounting for performance variation than have efforts to discriminate athletes of varying achievement levels (Hanin & Syrjä, 1995, 1996). As Gould and Tuffey (1996) and others have pointed out, however, the IZOF model is limited in explaining the mechanisms by which mood states, anxiety, or specific emotions influence performance.

Elite athletes appear to be both capable of regulating reactions to anxiety-producing stimuli as well as perceiving potentially threatening situations as either positive or challenging (e.g., Hardy, Jones, & Gould, 1996). The effects of anxiety and arousal on attentional processing have also received empirical evaluation (Janelle, Singer, & Williams, 1999; Murray & Janelle, 2000; Vickers, Williams, Rodrigues, Hillis, & Coyne, 1999; Williams, Vickers, Rodriques, & Hillis, 2000). Again, how these attributes differ as a function of expertise, as well as how these capabilities develop, has lacked scientific exploration. A rare exception is the work of Williams and Elliott (1999), who examined expert-novice differences in visual search characteristics and performance among karate athletes who participated in a simulated combat situation. Results indicated that although both groups exhibited notable shifts in visual attention as a function of anxiety, expert search patterns were more robust to the anxiety manipulation than were those of novices, thus indicating that experts are capable of maintaining consistency in attentional allocation in spite of emotional variability. These findings corroborate less mechanistic accounts that describe the emotional characteristics of expertise (e.g., Janelle, in press; J.G. Jones, Hanton, & Swain, 1994; Woodman & Hardy, 2001).

Psychological Skills

Early research efforts to determine the involvement of psychological skills among athletes of varying skill levels were initiated during the late 1970s with the influential work of Mahoney and Avener (1977), who studied psychological skill usage among successful and less successful gymnasts. Later work (Gould, Weiss, & Weinberg, 1981; Grove & Hanrahan, 1988; Highlen & Bennett, 1979; Orlick & Partington, 1988; Spink, 1990) followed a common purpose to describe skill level differences in the use of mental skills. Through a variety of self-report assessments (using several different instruments), the collective results of these investigations indicated that the following traits characterized the relatively more successful or higher skill level athletes: commitment to the sport and to quality training (including simulation training); goal setting; concentration and anxiety management; self-confidence; use of imagery and mental preparation; and mental training. However, the self-reported ratings, as well as questionable reliability and validity of some of the instruments used in these investigations, restrict the ability to make confident conclusions on psychological skill usage and how it may differ between elite and nonelite samples.

Later efforts have employed variations of the Ottawa Mental Skills Assessment Tool (OMSAT and OMSAT-3*) as a means to differentiate mental skill utility among athletes of differing skill levels. Notable studies in this area have included the work of Bota (1993), Stevenson (1999), Wilson (1999), and Durand-Bush, Salmela, and Green-Demers (in press). Collectively, across a variety of sports that range from synchronized skaters to hockey players, findings indicate a propensity among relatively elite athletes to score higher in commitment, goal setting, competition planning, self-confidence, stress reactivity, focusing, and refocusing. Moreover, results indicate that elite athletes use mental skills more than their nonelite counterparts in both training and competition (e.g., Wilson, 1999). Though valuable in describing what skills successful athletes employ in training and competition, literature in the psychological skills arena of expertise research has failed to examine the specific means by which these skills are implemented into the training and competitive setting, and it has also neglected to evaluate how these skills are developed.

Summary

The expertise approach, whether explicitly followed or implicitly present in research designs, has yielded valuable information concerning the development of expertise and has provided an indication of some of the mechanisms responsible for the expert advantage in sport. Expert sport performers in both self-paced and externally paced tasks develop a deeper, more intricate knowledge base by which to form representations of typical sport scenarios; they are more efficient and effective in recognizing and responding to structured game situations; they are more capable of matching appropriate strategies and tactics to game situations, which allows them to respond more effectively; they are more attuned to the richest informational sources provided in the visual scene, which enables them to make efficient and appropriate decisions; and their attentional and coordination capabilities appear to be less influenced by variations in affective states. Despite the wealth of scientific data derived from variations of the expertise approach, the current state of knowledge in the study of expertise is quite limited, with constraints on advancement potentially imposed by the nature and derivation of the expertise approach. As such, some areas of consideration for future research efforts are proposed as follows.

Critical Issues for Future Research

In the following section, we present a brief (and by no means exhaustive) summary of general topics and specific issues that have yet to be addressed or have not been fully resolved in the development of sport expertise. Indeed, developmental considerations for sport expertise, opportunities for deliberate practice, as well as coaching influences (among other topics) are areas of critical importance to our understanding of expertise. Given their extensive coverage in other sections of this book (see chapters 3, 4, 5, and 11), they have not been included here but certainly warrant further exploration.

The Development of Competitive Toughness and Emotional Regulation

In the context of our current understanding of expert performance, the relative contribution of competitive experiences has been largely de-emphasized in favor of general descriptions of the requirements for deliberate practice. Indeed, no known research to date has documented the amount of expert performance variance accountable by exposure to competitive settings. However, from an intuitive standpoint, one could certainly contend that to be effective in evaluative settings, the capability to compete has to be learned. Systematic and sport-specific training creates an athlete who is physically, technically, tactically, and perceptually capable of performing the requisite skills to consistently execute precise, consistent, efficient, and effective movements in benign settings. However, each of these performance components is inherently dependent on effective emotional regulation in the dynamic, often hostile sporting environment. Without competitive experience, it is difficult to imagine how anyone can acquire the self-regulatory capabilities to deal with the wide array of internal (emotional, cognitive) and external distractions that arguably cannot be experienced outside of the competitive arena.

Russell (1990) found that elite athletes progressively de-emphasized physical and technical components of performance while relying more on metacognitive skills. Though largely speculative, he suggests that novices and intermediate performers are less focused on these metacognitive skills in favor of physical and technical emphases. This prediction has been supported by Durand-Bush and Salmela (2001), who indicate that experience in the competitive setting is critical to the development of expertise in sport. Likewise, Cleary and Zimmerman (2001) and Jack, Kirshenbaum, Poon, Rodgers, and Starkes (1999) demonstrated that experts develop refined levels of metacognitive strategies. Whereas research has been done to determine the extent of deliberate practice that is needed for expertise, efforts should be undertaken to determine the amount and type of exposure to competition that is needed to hone competitive psychological skills. One might contend, in fact, that hours accumulated in competitive settings are a form of "deliberate experience" (where participants actively involve themselves in competition) and that such experience is necessary for experts to acquire the needed skills for effective performance in evaluative settings.

Critical Issues Related to Psychophysiology and Genetics

Though gaining in popularity over the past several years, the utilization of psychophysiological measures to study expert performance is underrepresented in the literature. The increasing implementation of psychophysiological assessment has occurred largely due to the increased comprehension of psychophysiological indexes and their relative affordability as compared to a decade ago. Some possibilities for implementation of psychophysiological research methods in the study of expert performance are outlined as follows.

Behavioral geneticists have typically focused on the relationship between general cognitive ability *(g)* and nonsport aptitude. Aside from *g* (and potentially related to *g*), genetic influences on the speed of information acquisition and processing might significantly influence sport expertise. These influences include attentional considerations and the influence of potential innate limitations, such as attention deficits and dyslexic learning disabilities. For example, despite the lack of attention devoted to understanding the influence of learning disabilities on sport performance, it is relatively safe to assume the following: Innate factors influence the way people process information in academic and social aspects of life; therefore, they also significantly affect sport performance. In fact, recent theory in this area has implicated the cerebellar regulation of a number of physiological factors that characterize those with dyslexia (e.g., Fawcett & Nicholson, 1995, 1999).

A wealth of information has recently emerged that examines expertise in performance domains other than sport, in addition to studies that regard the acquisition of skill by use of event-related brain potentials (ERPs) and neural imaging techniques (functional magnetic resonance imaging [fMRI] and magnetoencephalography [MEG]). Although these areas of research do not directly involve sport performance and although obvious differences between sport and other performance domains do exist, it still may be beneficial for researchers to gain an understanding of the basic mechanisms involved in skill acquisition and expertise. Most notably, Elbert and his colleagues (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995) compared changes in cortical plasticity (reorganization of the cerebral cortex) of string musicians and nonmusicians using magnetic source imaging. Results showed that the cortical representations of the digits of the left hand (the string hand) were "substantially enlarged" for string players compared to nonmusicians, but no such differences were observed for the right hand (the bow hand). Further, researchers observed a correlation between the age at which string players began playing their instrument and the magnitude of change in the cerebral cortex, with those beginning at a younger chronological age resulting in increased cortical plasticity.

Additional research on musical expertise by Münte, Kohlmetz, Nager, & Altenmüller (2001) used ERPs to measure differences between musical conductors, musicians (pianists), and nonmusicians on an auditory localization task. Their results suggest that conductors were able to allocate increased attentional resources to predetermined target locations in the environment when stimuli were presented both focally and peripherally. The increased spatial tuning observed in the peripheral environment is of great advantage and necessity to the musical conductors' developing expertise as they stand in front of large orchestras. It appears as though the many hours of deliberate practice that orchestras must engage in may also have an effect on the cortex of conductors that is adaptive in nature.

Animal models have also added insight into the biobehavioral development and acquisition of motor skill proficiency. For example, Isaacs and colleagues (Isaacs, Anderson, Alcantara, Black, & Greenough, 1992) examined angiogenic effects in the cerebellar cortex of adult female rats after one month of repeated training. They found that motor skill learning and aerobic exercise training distinctly affect the plasticity of the cerebellar cortex.

Taken together, the aforementioned research may appear to favor environmental influences on skill acquisition. However, it may also be plausible that the cortex is predisposed to specific neural adaptations in response to the specific constraints of a given environment. With future research geared toward identifying the variance explained by acquired characteristics and hereditary predispositions, psychophysiological approaches may prove to be extremely useful in delineating the mechanisms that underlie expert performance.

Influences on Practice Effectiveness

As mentioned, agreement exists regarding the need for long hours of practice to develop "talent." However, without acknowledging the variety of potential influences on the overall quality of the practice environment, as well as how to structure training so that practice can be maintained, it remains difficult to provide meaningful training recommendations (Davids, 2000; Singer & Janelle, 1999; Starkes, Helsen, & Jack, 2001). Issues that warrant attention in this category include the following: the motivation to devote long hours to training; the type of practice (versus the amount of practice) that is required to attain expert performance; the conditions that characterize "perfect practice"; the variable that permits expert performance in practice to transfer to competitive and evaluative domains; and the mechanisms by which long hours of deliberate practice might influence the development of expertise. Furthermore, research is notably scarce in issues that deal with the identification of expert psychological skills and how those skills are developed.

Similarly, much of practice time is currently spent in observation of others. Significant lessons can therefore be learned by observing peers (teammates) in the competitive setting. Performers who strive for expertise eventually have to practice a task systematically to learn and refine it to expert levels, but having the opportunity to learn through modeling arguably speeds the progression to skilled performance. However, with regard to the amount of time available for observational learning (see Starkes, Deakin, Allard, Hodges, & Hayes, 1996;

Helsen, Starkes, & Hodges 1998), especially in team sports where athletes have the opportunity to watch and learn from others, it is perhaps unrealistic to assume that careful attention to detail in these situations does not facilitate skill acquisition and eventual expertise. Furthermore, observing others' success in the competitive setting arguably provides the relative novice with the necessary conviction (self-efficacy) to believe that they too can be successful in the competitive arena (Bandura, 1997).

Summary

As may have become evident throughout this chapter, the absence of a specific, detailed, and testable theory has arguably compromised the ability to systematically advance the scientific study of expertise. The expertise approach, though providing a viable framework to guide expertise research over the past two decades, is not a theory per se of expertise. Likewise, it is inherently biased toward accounting for environmental influences (Heller & Zeigler, 1998; Rowe, 1998). Devaluing hereditary input to account for at least some of the variability in expert performance contradicts one of the most accepted foundational assumptions that concern the development and reorganization of human behavior and performance: the notion that over time, organisms evolve. They do so in accordance with specific adaptations to respond more appropriately and effectively in an ever-changing and dynamic environment. As such, they are also dependent on the particular experiences that are specific to one's culture and environment. By suggesting that inherent differences in innate predispositions to expertise do not exist, researchers therefore dismiss ideas that concern evolution and natural selection. Though not universally agreed on, the upper limits of human performance are largely dictated through years of evolution that have shaped and molded the potential for expertise among human beings.

A concept that is potentially lost in evolutionary arguments for expertise is that evolution reflects learning. Living organisms learn to adapt to meet the demands of their environment and to ensure that their offspring carry the genetic markers of these adaptations from one generation to the next. As such, adaptations as a result of deliberate practice will predispose the next generation for superior performance in those activities toward which their predecessors devoted most of their energy, effort, and training. As such, Hebb's (1949) statement that expertise "is a product of 100% nature and 100% nurture" is clearly accurate.

If we were to accept this argument, from where might a viable theory emerge in which the genetic and environmental contributions to expertise are illuminated? Contemporary theories of coordination and control of motor actions provide promising perspectives for the development of a comprehensive and practical theory of expert performance. Although traditional information-processing approaches to understanding skill acquisition remain prominent in cognitive psychology and elsewhere, a paradigm shift has arguably occurred in the field of motor behavior. It is a shift in which ecological accounts of coordination dynamics, invariants, affordances, and control parameters have replaced traditional cognitive terms, such as memory representations and response programming (for reviews, see Davids, Williams, Button, & Court, 2001; Williams, Davids, & Williams, 1999). Although stringent ecological accounts remain (or interpretations of them), far fewer restrictive orientations have emerged, which has led to the development of integrative frameworks in which traditional cognitive factors such as intention, attention, personality, and emotion act as control parameters that organize efficient movement patterns.

In 1994, Abernethy, Burgess-Limerick, and Parks reviewed differing approaches to the study of expertise and queried whether competing theoretical orientations would converge or diverge. Indeed, their recommendation that relative convergence would advance understanding of expert performance is beginning to be realized. Broadly considering the "state of the union" in the study of expertise, these integrative approaches hold perhaps the greatest promise for a workable theory. They account for the performing organism within the context of the environment while considering the task for which control must be exerted.

The notion of person, task, and environmental interactions was originally conceptualized by Newell (1986), but it has only recently been integrated in a way that may appeal to researchers who emanate from traditional cognitive perspectives as well as contemporary ecological approaches. Researchers will likely make closer approximations in forthcoming attempts to describe and explain expertise by comprehensively accounting for the respective influences on action by way of task and environmental constraints, in addition to organismic constraints that include hereditary influences. In contrast to the occasionally reductionist, self-confirming nature of expertise research to date, future research efforts will more than likely lead to the identification of the components of a general theory of expertise for sport. It will be a theory in which researchers consider the interactive and multiple influences on expertise, and it will comprise real and practical applications toward selection and training of aspiring expert athletes.

EXPERTS' COMMENTS

Question

In this chapter, Jannelle and Hillman suggest that although expertise research has considered many of the "learned" factors associated with experts, we need to also consider how talent (or genetic factors) may play a role. How important is a coach's ability to "recognize talent" in determining who will eventually become an expert athlete?

Coach's Perspective: Nick Cipriano

In the early stages of athletic development, no one can predict with a high degree of certainty which athletes will rise to the top and achieve excellence. Even in an extreme case, where a young athlete displays all the characteristics of greatness and is vastly superior to his or her peers, talent alone (in my experience) is a weak predictor of future success because the journey to expertise is such a long process. Moreover, because of the variance in physical maturation rates, it is entirely possible that the athlete who is seen as a talent at age 13 could well prove otherwise by age 16. Of course, the opposite is also true. One such example is Michael Jordan, perhaps the most celebrated basketball player of all time. He was cut from his high school basketball team because he did not display (according to his coach) what it was going to take to be successful. Fortunately, Jordan paid little attention to the coach who failed to recognize his persevering attitude. Through rigorous practice, Michael Jordan perfected his technical/tactical skills, which later propelled him to greatness. Michael Jordan's story is likely the most celebrated incident that provides the strongest support for Ericsson's theory of deliberate practice.

Player's Perspective: Therese Brisson

Janelle and Hillman suggest that although research has considered many of the learned factors associated with experts, genetics (or genetic factors) may play a considerable role. Genetics plays an important but sometimes sad role in high-performance sport. For example, 50 years ago, the average size of the NHL hockey player was about 5′ 7″ and 150 lbs. Of course, today the average size is closer to 6′ 0″ and 200 lbs. Smaller players are the exception, not the rule. Interestingly enough, the average size of players in the women's event at the 1998 Olympics was 5′ 6″ and 150 lbs. Since then, in the women's game I have observed the trend toward bigger players (more players close to 6′ 0″ and 200 lbs. are appearing on national team rosters). I'm glad to have played when I did, because 10 years from now I would be too small to make the team (I'm 5′ 7″ and 150 lbs.)! Body size is something we can't do too much about, but it is an important factor in many sports.

Other important physical skills in hockey are speed and quickness, which are not synonymous. Many talented hockey players in Canada will never make the national team because they are simply not fast enough. I have noticed that with training, many athletes can improve their overall speed—they get faster. However, no matter how much training they do, they can't get quicker. Quick feet, quick hands, quick movement, and quick thinking are critical in hockey, yet quickness does not seem to be a trainable skill; it appears to be "hard-wired." This is where genetics can be a little sad because no matter how much training athletes do, they will never be quicker. After the window of opportunity passes by, quickness doesn't appear to be something we can do much about.

We know that many factors influence athletic performance. Physical skills; technical and tactical skills; psychological and emotional skills; training; nutrition; and access to good coaching, facilities, and equipment are all important. We actually know a lot about these things. Using historical information and regression analysis, we can even predict what time an athlete will need to win the gold medal at the 1,000 m long-track speed skating event at the 2006 Winter Olympics. However, we know very little about genetic factors and their influence on athletic performance. I would say that talent identification remains the biggest challenge in high-performance sport. We are simply not very good at identifying who will eventually be an expert performer. One of the reasons for this is that the pattern of skills necessary for success in grassroots sport can be quite different than the skill set necessary at the elite level. For example, in youth sport, the bigger, stronger children are usually the most successful. However, this is not necessarily the case in international competition. In my sport, all the athletes that get to the international level can skate, pass, and shoot. Most athletes all fall within a pretty similar range for strength, speed, and conditioning too. I have heard NHL players joke about players who excel in fitness testing. They are in such great shape but can't compete on the ice. A different skill set is required. The thing that separates the good players from the less talented is the ability to make good decisions under pressure. This is difficult to evaluate in 8- to 10-year-olds.