Journal of Experimental Psychology: Applied
2007, Vol. 13, No. 3, 115–123

1076-898X/07/$12.00 DOI: 10.1037/1076-898X.13.3.115

Capturing Naturally Occurring Superior Performance in the Laboratory: Translational Research on Expert Performance

K. Anders Ericsson
Florida State University, Tallahassee

A. Mark Williams
Liverpool John Moores University

One of the central challenges to studying highly skilled performance in the laboratory is methodological. It is necessary to develop standardized methods that allow investigators to make experts repeatedly reproduce their superior performance in the laboratory. The recent increase in demand for translational research has raised related issues of how everyday phenomena, such as successful clinical treatments and expert achievement, can be reproduced in the laboratory and how laboratory studies of these phenomena can lead to successful interventions in everyday life. The expert-performance approach was developed as a framework for capturing, analyzing, and accounting for complex acquired skills and adaptations. Performance is initially captured and elicited in the laboratory using tasks representative of core activities in the domain. Process-tracing measures are employed to identify the mechanisms that mediate the reproducibly superior performance. Finally, the factors responsible for the development of the mediating mechanisms are studied by a retrospective analysis of training activities, such as deliberate practice, as well as genetic prerequisites. The principles and mechanisms discovered need then be validated using more traditional longitudinal and experimental designs.

Keywords: expertise, skill acquisition, applied research, performance enhancement

During the last 5 years an impressive number of scholarly books have been published on topics related to expertise and expert performance (Boshuizen, Bromme, & Gruber, 2004; Chaffin, Imreh, & Crawford, 2002; Ericsson, Charness, Feltovich, & Hoffman, 2006; Feist, 2006; Ferrari, 2002; Hoffman, 2007; Kurz-Milcke, & Gigenrenzer, 2004; Montgomery, Lipshitz, & Brehmer, 2005; Runco, 2007; Simonton, 2004; Starkes & Ericsson, 2003; Sternberg, & Grigorenko, 2003; Tetlock, 2005; Tsui, 2003; Weisberg, 2007; Williamon, 2004; Williams & Hodges, 2004). In these books, scientists describe a body of methods that can be used to study the structure and acquisition of high levels of achievement across a wide range of different domains of expertise, such as medicine, sports, teaching, chess, and music. The study of expertise has important theoretical and practical implications for skill acquisition and performance enhancement across domains. An examination of changes in the structure of performance during the extended development of expert performance will inform scientists both about potential invariant limits for improvement as well as effective methods for enhancing many different aspects of performance. Moreover, this body of research can be used to help test and refine existing models of skill acquisition, thereby potentially making significant contributions to theories of general abilities and skills.

K. Anders Ericsson, Florida State University; A. Mark Williams, Liverpool John Moores University, Liverpool, United Kingdom.

This article was prepared in part with support to the first author from the FSCW/Conradi Endowment Fund of Florida State University Foundation. The authors want to thank Phil Ackerman for his valuable comments on earlier drafts of this article.

Correspondence concerning this article should be addressed to Dr. K. Anders Ericsson, Department of Psychology, Florida State University, Tallahassee, FL 32306-4301. E-mail: ERICSSON@PSY.FSU.EDU

In light of this growing interest in the scientific study of expertise and expert performance, our goal in this special issue is to bring together several novel research papers focusing on the theme of how best to capture expert performance across domains. The papers presented provide examples of how superior performance, often naturally occurring in everyday contexts, may be identified and reproduced in the laboratory to allow examination of the mechanisms that differentiate expert from less proficient performers. In this introductory paper, we set the scene by providing a brief overview of some important general issues. We begin by considering the historical relationship between experimental research in the laboratory and the implications that have been derived for everyday problems and concerns.

The Relationship Between Experimental Laboratory Studies and Everyday Problems: A Historical Perspective

Hugo Münsterberg is arguably one of the most influential psychologists in the area of Applied Psychology and his professional development is intriguing (Benjamin, 2006). In 1898 Münsterberg claimed: “This rush toward experimental psychology is an absurdity. Our laboratory work cannot teach you anything which is of direct use to you in your work as teachers” (reproduced from Benjamin, 2006, p. 415). A decade later in 1908 he argued that “What is needed is to adjust research to the practical problems themselves and thus, for example, when education is in question, to start psychological experiences directly from educational problems” (reproduced from Benjamin, 2006, p. 420). He proposed that applied psychology should have the same relationship with scientific psychology as engineering has to physics. Many of the most influential achievements in psychology have resulted from using principles of “engineering” to solve practical problems and discoveries of highly reproducible phenomena in everyday life. For example, Alfred Binet (Wolf, 1973) developed the first intelligence tests to predict children's ability to succeed in school. Jean Piaget (Bryant, 1995) became interested in robust systematic errors in children's thinking while he standardized a translated version of a British intelligence test intended for French children. The empirical phenomena associated with these everyday tasks are strikingly robust and can often be reproduced with individual participants or small samples of participants, such as the failure to conserve volume in young children (Piaget, 1965). During the same period, laboratory studies became increasingly sophisticated with greater experimental control and enhanced measurement sensitivity.

At the centennial of Wilhelm Wundt's opening of the first psychology laboratory, several prominent scientists contributed to an edited book titled "The first century of experimental psychology". In a concluding chapter, William Estes (1979) noted that the efforts of experimental psychologists to build theories based only on results from laboratory studies may be acceptable as a short-term criterion for progress of a science. However, he continued by suggesting that ". . . in the long-term, society demands something more—a demonstration that experimental and theoretical results have some implications for practical affairs" (Estes, 1979, p. 626). He also felt that there was no reason for believing that the ". . .results of laboratory studies of isolated behavioral subsystems could ever be extrapolated to explain or predict how organisms adjust to their normal environments outside the laboratory" (p. 626). However, he did acknowledge that "within some restricted domains, experimental psychologists have indeed been able to *demonstrate* that the gap between the laboratory and the world of everyday affairs can be bridged with some success" (p. 629, italics added). He pointed to 2 successful subdisciplines, namely engineering psychology and applied behavior analysis and modification, where relations uncovered in the laboratory have been generalized to behavioral interventions in everyday life.

In the 1970s and 1980s several scientists criticized the ecological validity of laboratory research and its relevance for everyday life (Gibson, 1978; Neisser, 1976; Rogoff, & Lave, 1984). Neisser (1982) questioned whether a hundred years of laboratory studies had led to any useful insights into practical and interesting aspects of memory in everyday life. Neisser's (1982) argument for ecological validity led many cognitive psychologists to leave the laboratory to study the complex structure of everyday-life activities. Banaji and Crowder (1989) claimed that studies of everyday memory led to a lack of experimental control with a resulting loss in generalizability. Many of the leading researchers in the study of memory argued that the laboratory and ecological approaches could coexist and should complement, rather than replace, each other (e.g., see Klatzky, 1991; Loftus, 1991; Neisser, 1991; Tulving, 1991). Roediger (1991) reviewed evidence for the possibility of importing some everyday phenomena into the laboratory, such as research on the tip-of-the-tongue phenomenon, feeling of knowing, eyewitness testimony, and reality monitoring.

This debate between laboratory studies and applications to everyday phenomena has taken on a renewed urgency as the pressure for academics to attract Federal funding increases and at the same time agencies are requiring more transparent connections between societal concerns and the theories and results of laboratory studies. In recent years, several researchers, especially in medicine and the health sciences have started to question the separation of basic and applied science in an effort to encourage translational studies that explicitly build bridges between the 2 types of research within a single project. We briefly review these new developments before discussing how recent advances in the study of expertise and expert performance can provide particularly attractive and robust empirical phenomena for this type of research.

Translational Research: Bridging the Gap Between Science and Practice

There is increasing interest in translational research that examines how scientific findings in the laboratory can be converted into effective interventions in society. This interest has led many scientists in different academic disciplines, such as medicine and health-related sciences, to highlight the need for a more interactive and bidirectional exchange between researchers in the laboratory and the field of application. For example, in a recent issue of the American Psychological Society's publication *The APS Observer*, Vernig (2007) proposes how translational research can bridge the gap between science and practice. The traditional view is that the translational process is unidirectional where the results from theoretically motivated laboratory studies are translated into designed interventions in the field. However, it may be as important to move in the other direction, where "[B]basic researchers can examine the components of the multifaceted treatment programs in the laboratory under controlled conditions with high internal validity to investigate and isolate specific methods that are responsible for meaningful clinical improvement." (Vernig, 2007, p. 29).

This argument is compelling in sciences with associated clinical activities, such as health psychology and medicine. However, it should have even broader relevance. For example, scientists applying for Federal funding have for a long time been asked to present an introductory paragraph to illustrate how the proposed research addresses issues relevant to societal problems. Translational research goes beyond this requirement and requests a more complete translation of the studied phenomena in the laboratory to their implications for the everyday phenomena of societal relevance. Once contacts with researchers in the field are made, it becomes clear that successful translation requires an interactive adjustment of both implications as well as the hypotheses and design of the laboratory research. Francesco Marincola (2007), one of the pioneers of the translational research movement, states that "The contemporary scientific establishment equates hypothesis test to good science. This stance bypasses the preliminary need to identify a worthwhile hypothesis through rigorous observation of natural processes" (p. 1). Pioneers of the Scientific Revolution spent extended periods of time carefully gathering and observing information before the design and execution of experimental studies in the laboratory. Marincola (2007) writes: "It is true that facts can only be confirmed by experimentation that is reproducible and testable; to achieve this goal, experiments are controlled, ideally, by testing one variable a the time. However, hypothesis testing is not meant to validate the foundation upon which the hypothesis itself is based. Instead, experimentation and observation should lead to an accurate description of the facts upon which we could base a relevant hypothesis" (p. 2). Proponents for translational research recommend that researchers identify treatments that are effective in everyday life and then attempt to bring them into the laboratory. "Translational research can help identify not only *what* works in psychotherapy but also *how* it produces beneficial results." Vernig (2007, p. 29). The issue of how one would be able to demonstrate with appropriate scientific evidence that the treatment process brought into the laboratory setting really captures the essential characteristics of the successful treatment in everyday settings is at the theoretical core of the topic of this special issue. This leads us to review the experimental study of perception and cognition and its relation to applications in everyday life.

Studies of Perception, Memory, and Cognition With Experimental Methods

Several of the pioneering studies of perceptual-motor and cognitive phenomena in everyday life focused on striking phenomena that could be easily confirmed and had important theoretical implications. Alfred Binet's (1893/1966; 1894) studies of everyday and exceptional memory by mental calculators and chess players was motivated by his doubts that memory for nonsense syllables, as studied by Ebbinghaus (1885/1964), was mediated by the same types of processes as those underlying exceptionally superior memory performance. Based on field experiments with mental calculators and memory experts, and interviews with chess players, Binet (1893/1966; 1894) discovered the important role of knowledge and skill in the memorization of matrices of digits and the storing of chess positions in memory to allow "blindfold" chess play (i.e., play without a visible chess board). Bryan and Harter (1899) studied high levels of telegraphy performance and concluded that these advanced levels of skill are mediated by complex acquired mechanisms that are comparable to learning "a distinct language, almost or quite as elaborate as the mother tongue" (p. 359).

Many different phenomena were identified and brought into the laboratory. One of the earliest successes was the study of skilled typing, where stable individual differences in the rate of skilled performance often ranged from 20 to 140 words per minute (Book, 1924, 1925a, 1925b). Other phenomena such as the ability of some children to hold visual images of pictures (eidetic imagery) were shown to reflect a unique subjective experience rather than a superior ability to retain visual information (Haber, 1979). Although demonstrations of exceptional memory in everyday life could be replicated in the laboratory, their relevance was restricted to particular types of tasks, such as memorizing long lists of digits and consonants, and mediated by acquired memory skill using mnemonic encoding techniques that have been practiced extensively (for recent reviews, see Ericsson, 2003; Wilding & Valentine, 2006).

Most researchers started to accept the assumption that superior performance appears to be limited to a domain of activity and expertise. Increased interest in skill acquisition and expertise was stimulated by the development of a theoretical framework for describing the acquisition of various types of everyday skills (Fitts & Posner, 1967) and a general theory of expertise proposed by Simon and Chase (1973) based on the pioneering work of de Groot (1946/1978). These theoretical frameworks assumed a gradual change toward automated behavior and the acquisition of increasingly complex perceptual patterns and actions as function of engagement in domain-related activities.

The study of exceptional individuals, such as authors, scientists, composers, and athletes, runs up against a problem elegantly described by Cronbach (1957) in his paper on 'the two disciplines of scientific psychology.' He argued that "the experimenter is only interested in variations that he himself creates" (Cronbach, 1957, p. 671) and a researcher using correlational methods "finds his interest in the already existing variation between individuals, social groups, and species" (p. 671). Given that individuals in most domains only achieve at an international level after a long period of intense preparation (Ericsson et al., 1993; Simon & Chase, 1973) and consequently make their major achievements in their 20ies, 30ies, 40ies or later (Lehman, 1953) and are only recognized as truly exceptional relatively late in their careers it is clear that we are dealing with the latter case. In fact, the vast majority of eminent individuals have been dead for a long time and it is only possible to study the correlation of biographical indicators of their career and accomplishments (Simonton, 2006). On occasion, scientists have brought in individuals whose performance was clearly superior to other people in the world for testing using standard laboratory measures of basic abilities. For example, Babe Ruth (Fullerton, 1921) was given a series of tests to measure speed of reaction, such as simple reaction time, which has in more recent large-scale studies been found not to be a consistent predictor of skilled performance nor even of differences between athletes and nonathletes (see Abernethy, 1987; Helsen & Starkes, 1999; Ward & Williams, 2003; for a review, see Williams, Davids, & Williams, 1999). The famous chess champion, Gary Kasparov (Der Speigel, 1987), was given a series of intelligence tests, however, such tests have not been found to correlate significantly with chess skill among skilled chess players (Roring, Ericsson, & Nandagopal, in press). Finally, one of the world's most prodigious mental calculators, Shakuntala Devi, who was able rapidly multiply in her head large numbers, such as 7,686,369,774,870 * 2,465,099,745,779, was studied in the laboratory by Arthur Jensen (1990), who is the famous researcher of general intelligence (*g*) (Jensen, 1998). From the laboratory tests Jensen (1990) concluded that her exceptional performance "must depend largely on the automatic encoding and retrieval of a wealth of declarative and procedural information in long-term memory rather than on any unusual basic capacities" (p. 259), such as psychometric *g* or the speed of elementary information processes.

Simon and Chase's (1973) influential theory of expertise allowed researchers to avoid the problem of studying the complex performance of experts directly and made theoretical predictions for performance of novices and experts on laboratory tasks. Experts and novices were briefly presented with 2 types of stimuli, namely unfamiliar positions from actual chess games (representative stimuli from their domain of expertise) and chessboards with randomly rearranged chess pieces. In a wide range of domains investigators showed that experts displayed dramatically superior memory to novices for representative stimuli, but not for randomized stimuli. The Simon and Chase (1973) theory of expertise with its monotonically increasing memory performance (reflecting a larger body of increasingly complex patterns) encountered several types of criticisms. Ackerman (1987) showed that during the acquisition of skilled performance the mediating processes change as a function of experience/practice in a manner consistent with the Fitts and Posner (1967) model. Ericsson and Smith (1991) criticized the assumption of improved performance as a function of experience and pointed to several cases where increased domain-related experience is not associated with improved performance (for more recent extensive reviews supporting this claim, see Choudhrey, Fletcher, & Soumerai, 2005; Ericsson, 2004; Ericsson, Whyte, & Ward, 2007). For example, it is possible for someone have very extensive experience of various activities without displaying superior performance on common representative tasks related to their expertise. Lewis (1981) found that research mathematicians, who had worked with algegra on a daily basis for decades, are not significantly faster in solving algebra problems than undergraduates.

Ericsson and Smith (1991) also argued that studying the performance of experts and novices on a memory task did not capture the stable essence of expert performance. For example, it is possible for college students to improve memory performance for briefly presented chess positions that matches the original performance of chess experts and even chess masters after only 50 hours of specialized training (Ericsson & Harris, 1990; Gobet & Jackson, 2002); it takes over 20 times longer to attain chess expertise that matches that of a chess Grandmaster. Finally, experts with extensive knowledge are often assumed to master their domain and consequently asked for advice about many different aspects related to their domain of expertise, even outside their limited area of specialization. This assumption of general knowledge and mastery is frequently not supported. For example, Reif and Allen (1992) found that Physics professors at Berkeley are not significantly superior in solving all types of problems on tests for undergraduates in introductory courses.

The central problem with expert performance is that it is not easily reproduced in the laboratory. There are many laboratory studies of skill acquisition that have measured the development of performance in randomly recruited college students under controlled conditions (Ackerman, 1987; Anderson, 1982, 1987; Proctor & Dutta, 1995). However, the majority of researchers have only studied skill acquisition experimentally with recruited participants over a limited time period, typically only a few hours of practice (for notable exceptions, see Ackerman, 1987; Ackerman, 1990; Baddeley & Longman, 1978; Donchin, 1989; Pirolli & Anderson, 1984; and Shiffrin, 1996 for a review). In contrast, development of the highest levels of performance is known to take over a decade (Simon & Chase, 1973; Lehman, 1953). To address the earlier discussed problems with selection of experts based on social criteria, Ericsson and Smith (1991) proposed that researchers need to identify the essence of expertise, namely those types of key activities where experts consistently excel when compared to less accomplished individuals, even though the less skilled individuals have tried for years to reach the same level. For example, Kasparov has consistently defeated all other chess masters in repeated games during World Champion matches, Babe Ruth hit more home runs than any of his fellow baseball players, expert medical doctors are able to treat patients with better health outcomes than less accomplished doctors, and expert tennis players repeatedly overcome less skilled competitors on various playing surfaces on the professional circuit. Only when we can systematically reproduce the superior performance under controlled conditions can we examine experimentally the mechanisms mediating the significantly superior levels of performance on the core representative tasks. Only with repeated observations and experimental variations are we likely to be able to generate models and theories to explain the structure of expert performance. The first critical step is to be able to identify significantly superior performance and then design conditions for eliciting this performance upon demand in controlled situations either in the laboratory or field setting. Once the performance can be reproduced, it is possible to identify the mediating mechanisms with experimental techniques and the collection of process data, such as eye-movements and "think aloud" or retrospective verbal reports.

Capturing Reproducibly Superior Performance Under Standardized Conditions

In everyday life, experts may rarely encounter the same challenges under similar conditions. Therefore, it is conceivable that variation in their performance may be because of differences in the types of challenges encountered rather than in ability and skill. For example, it is likely that some doctors have to treat clients with more complex and lethal diseases, that some flight controllers will be assigned to jobs at airports with greater difficulties because of weather and traffic intensity, and, in sport, an individual's performance is at least partly determined by the strength of the opponent. Consequently, individual differences in their current average level of performances may be, at least in part because of contextual factors. The key challenge for anyone interested in individual differences is to control the task and performance conditions so everyone encounters the same representative challenges and associated tasks regardless of their level of experience and perceived expertise.

In his pioneering work, de Groot (1946/1978) was able to capture the superior performance of world-class chess players by presenting a series of standardized tasks. He identified critical game situations by searching through unfamiliar chess games between chess masters. He presented the associated chess position to players during individual testing in a quiet environment and asked them to generate the next best move while they were thinking aloud. Subsequent research with large groups of chess players has shown that 15 min of testing with the task of making the best move for a series of selected chess positions is very highly correlated with the tournament ratings (van der Maas & Wagenmakers, 2005).

Following on from the work of de Groot (1946/1978), the expert performance approach has been proposed for studying expertise in a wide range of domains such as music, sports, and medicine (see Ericsson, 2006a; Ericsson & Smith, 1991; Williams & Ericsson, 2005). This approach identifies naturally occurring situations that require immediate action and capture the experts' superior selection or execution of action in the associated domain of expertise. These situations are then reproduced with appropriate context and demand for action under controlled conditions in the laboratory, such as, for example, a video clip of a game situation in soccer or tennis requiring an athlete to perform an action (see Williams & Davids, 1995; Williams, Ward, Knowles, & Smeeton, 2002), and the presentation of a musical score for sight reading (e.g., unrehearsed playing from sight; see Lehmann & Ericsson, 1993, 1996).

Although standardized tasks may have been designed to incorporate and simulate all essential factors, such as time stress and complexity of visual displays, there is no a priori assurance that performance on the standardized tasks will elicit the same processes that mediate performance in everyday life. To demonstrate that the laboratory tasks capture the expertise in question it is necessary to show that performance on the standardized tasks predict the gold standard of performance, namely performance in everyday life, such as absolute performance of athletes in individual events, tournament performance, World rankings, and other objectively measured performance indicators. It is often possible to go beyond correlation with its limitations (Cronbach, 1957) and one can collect various types of process measures during performance on the task, such as reaction times, along with process-tracing data such as eye-fixations and concurrent or retrospective verbal reports. It is possible to collect and compare similar process data from performance in everyday life, especially for athletes and musicians, who perform publicly and can be filmed and retrospective reports, can be elicited from them after the end of the public performance. It may be possible to recreate the conditions in the laboratory similar to those associated with a particular naturally occurring performance to allow comparison of data to identify the lack of any significant differences.

Once the performance has been successfully reproduced in the laboratory it is also possible to manipulate these situations experimentally by eliminating certain types of information and by introducing unexpected perturbations to test the validity of the collected reports and other process data (e.g., for some examples of how these procedures have been employed in sport, see Williams & Ericsson, 2005). This type of research has shown that the superior performance displayed by experts is directly linked to complex representations. These findings are consistent with the failure to find individual differences among skilled performers that are correlated with more "basic" differences in reaction times, intelligence, and spatial ability (for a discussion of sports, see Hodges, Starkes, & MacMahon, 2006; Ward & Williams, 2003; for a more general discussion of expertise and intelligence, see Ericsson, 2007; Ericsson, Roring, & Nandagopal, 2007a, 2007b; Horn & Masunaga, 2006). However, these patterns of findings differ from a large body of research on skill acquisition where ability differences are predictive of performance at various stages of practice (Ackerman, 1987, 2000).

There are domains of expertise where it has been difficult to capture expert performance with standardized tasks. For example, highly experienced psychotherapists are not significantly more successful in their treatment of patients than novice therapists are (Dawes, 1994). Reviews of decision making (Camerer & Johnson, 1991; Shanteau & Stewart, 1992) and political judgment (Tetlock, 2005) show that experts' decisions and forecasts, such as financial advice on investing in stocks or forecasting of political events, are not necessarily superior to those given by nonexperts. In creative domains (Feist, 2006; Runco, 2007; Simonton, 2004; Weisberg, 2007), it is impossible to reproduce the original discovery or invention and it is virtually impossible to predict when original ideas will emerge. For a scientist or an artist to generate novel ideas and products, it is essential for them to have knowledge of previously generated ideas and products, as rediscovery of someone else's ideas is not rewarded in any domain. Another prerequisite in most domains is that the individuals have the necessary tools to implement and express their ideas. Several scientists (Kozbelt, 2001; Winner & Casey, 1992) have demonstrated that experts are able to exert greater control over their performance and surpass novices in perceptual tasks. For example, Kozbelt (2001) showed that expert artists were able to copy visual stimuli more accurately than novices were. Similarly, Krampe and his colleagues (Ericsson, Krampe, & Tesch-Römer, 1993; Krampe & Ericsson, 1996) found that expert pianists have greater ability to reproduce a single interpretation of a piece of music than amateurs do.

The Development of Expert Performance

The expert-performance approach has now been successfully applied to a wide range of activities, such as medical diagnosis, surgical procedures, music performance, writing, painting, scrabble, darts, ballet, soccer, running, field-hockey, volleyball, rhythmic gymnastics, and tennis (Ericsson, 2006a, 2006b). The most interesting and exciting discoveries from studying the superior performance of experts is that it has been directly linked to complex representations that are specific to the domain of expertise and consequently, were developed as result of extended exposure and practice. Furthermore, there is considerable evidence to show that at least 10 years of engagement in dedicated and focused practice is needed before being able to win at an international level (Ericsson, 2006b; Simon & Chase, 1973).

More generally, diaries and retrospective estimates of weekly engagement in particular activities have demonstrated that not all domain-related activities are correlated with increases in performance. Ericsson, Krampe, and Tesch-Römer (1993) found that total amount of domain-related activities for musicians were not associated with differences in attained level of performance. The activity most closely related to level of performance was the amount of engagement in solitary practice as reflected by diaries and retrospective estimates. During solitary practice, musicians work on clear practice goals recommended by their teachers with methods designed to improve specific aspects of their performance with problem solving and through repetitions with feedback (deliberate practice). For a wide range of different domains of expertise, such as typing, foreign language interpreting, games, professions, and sports, it has been possible to identify deliberate practice activities that allow performers to improve aspects of their performance by designing practice activities (deliberate practice) that allow them to refine and modify mediating mechanisms to stretch their performance to a reach a new higher level. Krampe and Ericsson (1996) showed that when changes in music performance are studied across the life span it is important to distinguish the initial phase of acquiring expert performance, when deliberate practice is aimed at improving performance, from the professional phase of musicians when deliberate practice serves to maintain an already attained level of performance. The need for regular intense practice to merely maintain a level of performance in swimming and running is well known, whereas performance in some cognitive domains, such as chess, may not depend as much on maintained practice.

Several researchers have reported a consistent association between the amount and quality of solitary activities meeting the criteria of deliberate practice and performance in different domains of expertise, such as chess (Gobet & Charness, 2006), darts (Duffy, Baluch, & Ericsson, 2004), music (Lehmann & Gruber, 2006), many types of sports (Ward, Hodges, Williams, & Starkes, 2004), and several other diverse domains (Ericsson, 2006b). Most of these findings are based on retrospective estimates of deliberate practice and are correlational in nature. In addition, there are some reasons to be concerned about the ability of individuals to remember accurately their practice years, in some cases decades later. In the early study of musicians, Ericsson et al. (1993) were able to show significant correlations of durations of solitary practice between those summed for the diary week and those estimated for a typical week. In a more recent study, Bengtson et al. (2005)

showed that the retrospective estimates of practice during adolescence had high test-retest reliabilities when estimated by the musicians at 2 test occasions over a year apart. The reported level of practice was also found to correlate with degree of myelinization of different brain areas. Moreover, Ward, Hodges, Starkes, and Williams (in press) reported no differences between the recall of practice hours in current 12-year-old elite soccer players when compared with retrospective estimates of practice history hours for 13- to 18-year-old elite players when they were 12 years of age. In a recent review Côté, Ericsson, and Law (2005) discussed how independent retrospective estimates of the amount of practice by the performers themselves, their parents, and their coaches have been used to validate retrospective estimates of practice, but not estimates of other types of activities.

For investigators to be able to further our understanding of deliberate practice and its consequences for improved performance it will be necessary to conduct longitudinal studies of skilled individuals where the performance and practice activities are recorded objectively. Ideally, one should start with a large random sample of unselected individuals and encourage them to start training in an arbitrary domain of expertise and then follow them for a long time, to see who develops expertise and who does not. However, given that there is often around one outstanding performers per million recreational amateurs these types of studies would be difficult to conduct. However, it is feasible to study groups of individuals at systematically different levels of achievement for a limited period, such as a month, and then assess the effects on performance from natural variation in the amount and type of practice during this time (Ericsson, 2007). The ultimate validation of the effects of particular types of practice for individuals at different levels of achievement will come from experimental studies where expert performers are randomly assigned to different practice conditions. For example, in a study of international junior level soccer players, Helgerud, Engen, Wisloff, and Hoff (2001) demonstrated that additional high-intensity training for a randomly assigned group of elite players was associated with increases in performance during soccer matches.

In summary, the expert-performance framework has been used to demonstrate that it is possible to account for the large variability in performance in terms of hypothesized consequences of individual differences in sustained activity and accumulated deliberate practice. It is now essential to go beyond retrospective estimates of practice toward longitudinal studies of concurrent observation of practice and performance.

Contributions in the Special Issue

To facilitate progress in the scientific study of expert performance researchers should strive to explore the most appropriate methods for capturing expertise across domains. The methods employed should provide precise and reproducible measurements so that the development of performance can be objectively assessed. The performance of experts on these tasks should not improve significantly over repeated tests since the intention is to monitor stable processes that have been modified and adapted over extended periods of practice. In the special issue a series of papers are presented that illustrate how expert performance can be captured effectively under controlled laboratory conditions. The domains of study presented vary greatly and include board games such as SCRABBLE, everyday skills such as typewriting, and fairly specialized skills such as military reconnaissance, elite level sport, and canine agility.

In the first paper in the special issue Michael Tuffiash, Roy Roring, and Anders Ericsson examine expert performance in the domain of SCRABBLE. A combination of domain-representative laboratory tasks and standardized verbal ability tests are employed to identify the mechanisms differentiating elite- and average-level rated players and nonplayers. The authors also report retrospective estimates of current and accumulated practice activities to provide an insight into how the cognitive mechanisms that mediate the superior performance of elite players might have been acquired.

In a novel variant of the classical expert performance approach, Nina Keith and Anders Ericsson apply deliberate practice theory to intermediate-level performance in typing, a typical everyday skill. The authors evaluate the relative contribution of general measures of perceptual and motor abilities, typing experience, and task-specific skills to performance in typing. A combination of laboratory-based measures and retrospective estimates of practice activities are employed. An attempt is made to identify the practice activities that influenced the acquisition of skill in typing.

Nancy Cooke, Jamie Gorman, Jasmine Duran, and Amanda Taylor examine the nature of expert team cognition during the control of an uninhabited aerial vehicle (UAV), as commonly employed in military reconnaissance. Several 3-person teams learn how to take reconnaissance photographs of designated targets in a synthetic task environment. The amount that the 3-person teams had worked together on other types of tasks was associated with superior performance. Of particular interest is the search for which aspect of the interactions between members of the group that mediated the superior performance of the teams with prior experience of working together.

Marcus Raab and Joseph Johnson identify the mechanisms underpinning expert decision-making in the sport of team handball, an Olympic sport which is played on basketball size courts predominantly in Europe. A film-based test of decision-making skill is employed by presenting film sequences from handball games extracted from competitive matches. Verbal report and eye movement data are reported to highlight the characteristics that differentiate elite and subelite handball players. A noteworthy aspect of this paper is the attempt to trace the development of expert performance over time using a longitudinal design involving 4 waves of data collection over a 2-year period. These data are used to elaborate on the authors' model of option generation, deliberation, and selection that may have implications for the structure of expert performance in many domains.

In the final paper in this special issue, William Helton examines expert performance in nonhuman animals. The performance of dog handlers and their expert, advanced, intermediate, and novice dogs is compared on agility courses. The performance and types of mistakes of dogs at different level of expertise is collected and analyzed to assess the structure of expert performance in canines. The author examines the implications for those interested in developing expertise in humans as well as in canine workers, with particular reference to the development of automaticity.

Overall, an eclectic mix of papers is provided to illustrate the many novel approaches that researchers are currently using to capture expert performance in different domains and populations. The ability to capture the essential aspects of performance under controlled conditions in both the laboratory and the field is critical if we are to advance our understanding of the mechanisms underpinning expert performance and how these are developed because of engagement in specific types of practice activities. This activity is particularly relevant in a culture that demands evidence-based practice in all areas of societal endeavor. When we are able to capture and analyze the reproducibly superior performance of experts in the relevant domains, experimental psychologists will be able to contribute to our analysis of the mechanisms responsible for this superior performance and engage in the interactive, bidirectional exchange between laboratory research and the field of application to develop evidence-based practices and superior professionals.

References

Abernethy, B. (1987). Selective attention in fast ball sports. II. Expert-novice differences. *Australian Journal of Science and Medicine in Sports, 19,* 7–16.

Ackerman, P. L. (1987). Individual differences in skill learning: An integration of psychometric and information processing perspectives. *Psychological Bulletin, 102,* 3–27.

Ackerman, P. L. (1990). A correlational analysis of skill specificity: Learning, abilities, and individual differences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 883–901.

Ackerman, P. L. (2000). A reappraisal of ability determinants of individual differences in skilled performance. *Psychologische Beiträge, 42,* 4–17.

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review, 89,* 369–406.

Anderson, J. R. (1987). Skill acquisition: Compilation of weak-method problem situations. *Psychological Review, 94,* 192–210.

Baddeley, A. D., & Longman, D. J. A. (1978). The influence of length and frequency of training session on the rate of learning to type. *Ergonomics, 21,* 627–635.

Banaji, M. R., & Crowder, R. G. (1989). The bankruptcy of everyday memory. *American Psychologist, 44,* 1185–1193.

Bengtsson, S. L., Nagy, Z., Skare, S., Forsman, L., Forsberg, H., & Ullén, F. (2005). Extensive piano practicing has regionally specific effects on white matter development. *Nature Neuroscience, 8,* 1148–1150.

Benjamin, L. T. (2006). Hugo Münsterberg's attack on the applications of scientific psychology. *Journal of Applied Psychology, 91,* 414–425.

Binet, A. (1894). *Psychologie des grands calculateurs et joueurs d'echecs* [The psychology of great calculators and chess players]. Paris: Libraire Hachette.

Binet, A. (1966). Mnemonic virtuosity: A study of chess players. (Original paper appeared in 1893 and was translated by M. L. Simmel and S. B. Barron). *Genetic Psychology Monographs, 74,* 127–162.

Book, W. F. (1924). Voluntary motor ability of the world's champion typists. *Journal of Applied Psychology, 8,* 283–308.

Book, W. F. (1925a). *Learning to typewrite.* New York: The Gregg Publishing Co.

Book, W. F. (1925b) *The psychology of skill.* New York: The Gregg Publishing Co.

Boshuizen, H. P. A., Bromme, R., & Gruber, H. (2004). Professional Learning: Gaps and transition on the way from novice to expert. Dordrecht, The Netherlands: Kluwer Academic Publishing.

Bryan, W. L., & Harter, N. (1899). Studies on the telegraphic language: The acquisition of a hierarchy of habits. *Psychological Review, 6,* 345–375.

Bryant, P. E. (1995). Jean Piaget (1896–1980). In R. Fuller (Ed.), *Seven pioneers of psychology: Behaviour and mind* (pp. 131–154). London, UK: Routhledge.

Côté, J., Ericsson, K. A. & Law, M. (2005). Tracing the development of athletes using retrospective interview methods: A proposed interview and validation procedure for reported information. *Journal of Applied Sport Psychology, 17,* 1–19.

Camerer, C. F., & Johnson, E. J. (1991). The process-performance paradox in expert judgment: How can experts know so much and predict so badly? In K. A. Ericsson & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 195–217). New York: Cambridge University Press.

Chaffin, R., Imreh, G., & Crawford, M. (2002). Practicing perfection: Memory and Piano performance. Mahwah, NJ: Erlbaum.

Choudhry, N. K., Fletcher, R. H., & Soumerai, S. B. (2005). Systematic review: The relationship between clinical experience and quality of health care. *Annals of Internal Medicine, 142,* 260–273.

Cronbach, L. J. (1957). The two disciplines of scientific psychology. *American Psychologist, 12,* 671–684.

Dawes, R. M. (1994). *House of cards: Psychology and psychotherapy built on myth.* New York: Free Press.

de Groot, A. (1978). *Thought and choice in chess.* The Hague: Mouton (Original work published 1946).

Der Speigel (1987). *Genieblitze und Blackouts: Der Spiegel testete Intelligenz, Gedächtniss und Schachkunst Garri Kasparows.* [Stokes of genius and blackouts: Der Spiegel tests the intelligence, memory, and chess ability of Gary Kasparov]. *Der Spiegel, 41,* 126–140.

Donchin, E. (1989). The learning strategies project. *Acta Psychologica, 71,* 1–15.

Duffy, L. J., Baluch, B., & Ericsson, K. A. (2004). Dart performance as a function of facets of practice amongst professional and amateur men and women players. *International Journal of Sport Psychology, 35,* 232–245.

Ebbinghaus, H. (1885/1964). *Memory: A contribution to experimental cognitive psychology* (Henry A. Ruger & Clara E. Bussenius, Trans.). New York: Dover.

Ericsson, K. A. (2003). Exceptional memorizers: Made, not born. *Trends in Cognitive Sciences, 7,* 233–235.

Ericsson, K. A. (2004). Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Academic Medicine, 79,* S70–S81.

Ericsson, K. A. (2006a). Protocol analysis and expert thought: Concurrent verbalizations of thinking during experts' performance on representative task. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman, R. R. (Eds.). *Cambridge handbook of expertise and expert performance* (pp. 223–242). Cambridge, UK: Cambridge University Press.

Ericsson, K. A. (2006b). The influence of experience and deliberate practice on the development of superior expert performance. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman, R. R. (Eds.). *Cambridge handbook of expertise and expert performance* (pp. 685–706). Cambridge, UK: Cambridge University Press

Ericsson, K. A. (2007). Deliberate practice and the modifiability of body and mind: Toward a science of the structure and acquisition of expert and elite performance. *International Journal of Sport Psychology, 38, 4*–34.

Ericsson, K. A., Charness, N., Feltovich, P., & Hoffman, R. R. (2006). *Cambridge handbook of expertise and expert performance.* Cambridge, UK: Cambridge University Press.

Ericsson, K. A., & Harris, M. S. (1990). *Expert chess memory without chess knowledge: A training study.* Poster presented at the 31st Annual Meeting of the Psychonomic Society, New Orleans, LA.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100,* 363–406.

Ericsson, K. A., & Smith, J. (1991). Prospects and limits in the empirical study of expertise: An introduction. In K. A. Ericsson & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 1–38). Cambridge: Cambridge University Press.

Ericsson, K. A., Whyte, J., & Ward, P. (2007). Expert performance in nursing: Reviewing research on expertise in nursing within the framework of the expert-performance approach. *Advances in Nursing Science, 30,* E58–E71.

Ericsson, K. A. Roring, R. W., & Nandagopal, K. (2007a). Giftedness and evidence for reproducibly superior performance: An account based on the expert-performance framework. *High Ability Studies, 18,* 3–56.

Ericsson, K. A. Roring, R. W., & Nandagopal, K. (2007b). Misunderstandings, agreements, and disagreements: Toward a cumulative science of reproducibly superior aspects of giftedness. *High Ability Studies, 18, 97*–115.

Estes, W. K. (1979). Experimental psychology: An overview. In E. Hearst (Ed.), *The first century of experimental psychology* (pp. 623–667). Hillsdale, NJ: Erlbaum, Publishers.

Feist, G. J. (2006). *The psychology of science and the origins of the scientific mind*. New Haven, CT; Yale University Press.

Ferrari, M. (Ed.). (2002). The pursuit of excellence through education. Mahwah, NJ: Erlbaum.

Fitts, P., & Posner, M. I. (1967). *Human performance.* Belmont, CA: Brooks/Cole.

Fullerton, H. S. (1921). Why Babe Ruth is greatest home-run hitter. *Popular Science Monthly, 99,* 19–21.

Gibson, J. J. (1979.) *An ecological approach to visual perception.* Boston, M. A.: Houghton Mifflin.

Gobet, F., & Charness, N. (2006). Chess. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman, R. R. (Eds.). *Cambridge handbook of expertise and expert performance* (pp. 685–706). Cambridge, UK: Cambridge University Press.

Gobet, F., & Jackson, S. (2002). In search of templates. *Cognitive Systems Research, 3,* 35–44.

Haber, R. N. (1979). Twenty years of haunting eidetic imagery: Where's the ghost?' *Behavioral & Brain Sciences, 2,* 583–629.

Helgerud, J., Engen, L. G., Wisloff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. *Medicine and science in Sports and Exercise, 33,* 1925–1931.

Helson, W. F., & Starkes, J. L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology, 13,* 1–27.

Hodges, N., Starkes, J., & MacMahon, C. (2006). Expert performance in sports: A cognitive perspective. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman, R. R. (Eds.). *Cambridge handbook of expertise and expert performance* (pp. 471–488). Cambridge, UK: Cambridge University Press.

Hoffman, R. R. (Ed.). (2007). *Expertise out of context: Proceedings of the sixth international conference on naturalistic decision making.* Mahwah, NJ: Erlbaum.

Horn, J., & Masunaga, H. (2006). A merging theory of expertise and intelligence. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman, R. R. (Eds.). *Cambridge handbook of expertise and expert performance* (pp. 587–611). Cambridge, UK: Cambridge University Press.

Jensen, A. R. (1990). Speed of information processing in a calculating prodigy. *Intelligence, 14,* 259–274.

Jensen, A. R. (1998). *The g factor: The science of mental ability.* Westport, CT: Praeger.

Klatzky, R. L. (1991). Let's be friends. *American Psychologist, 46,* 43–45.

Kozbelt, A. (2001). Artists as experts in visual cognition. *Visual Cognition, 8,* 705–723.

Krampe, R. Th., & Ericsson, K. A. (1996). Maintaining excellence: Deliberate practice and elite performance in young and older pianists. *Journal of Experimental Psychology: General, 125,* 331–359.

Kurz-Milcke, E., & Gigenrenzer, G. (2004). *Experts in science and society*. New York: Kluwer Academic/Plenum Press Publishers.

Lehman, H. C. (1953). *Age and achievement.* Princeton, NJ: Princeton University Press.

Lehmann, A. C., & Ericsson, K. A. (1993). Sight-reading ability of expert pianists in the context of piano accompanying. *Psychomusicology, 12,* 182–195.

Lehmann, A. C., & Ericsson, K. A. (1996). Music performance without preparation: Structure and acquisition of expert sight-reading. *Psychomusicology, 15,* 1–29.

Lehmann, A. C., & Gruber, H. (2006). Music. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman, R. R. (Eds.). *Cambridge handbook of expertise and expert performance* (pp. 457–470). Cambridge, UK: Cambridge University Press

Lewis, C. (1981). Skill in algebra. In J. R. Anderson, *Cognitive skills and their acquisition* (pp. 85–110). Hillsdale, NJ: LEA.

Loftus, E. F. (1991). The glitter of everyday memory . . . and the gold. *American Psychologist, 46,* 16–18.

Marincola, F. M. (2007). In support of descriptive studies: Relevance for translational research. *Journal of Translational Medicine, 5,* 1–3.

Montgomery, H., Lipshitz, R., & Brehmer, B. (Eds.) (2005). *How professionals make decisions*. Mahwah, NJ: Erlbaum.

Neisser, U. (1976). *Cognition and reality: Principles and implications of cognitive psychology.* San Francisco: Freeman and Company.

Neisser, U. (1982). Memory: What are the important questions? In U. Neisser (Ed.), *Memory observed: Remembering in natural contexts* (pp. 3–19). San Francisco: Freeman and Co (originally published in 1978).

Neisser, U. (1991). A case of misplaced nostalgia. *American Psychologist, 46,* 34–36.

Piaget, J. (1965). *The child's conception of number.* New York: Norton.

Pirolli, P. L., & Anderson, J. A. (1985). The role of practice in fact retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 136–153.

Proctor, R. W., & Dutta, A. (1995). *Skill acquisition and human performance.* Thousand Oaks, CA: Sage

Reif, F., & Allen, S. (1992). Cognition for interpreting scientific concepts: A study of acceleration. *Cognition and Instruction, 9,* 1–44.

Roediger, H. L. III. (1991). They read an article? A commentary on the everyday memory controversy. *American Psychologist, 46,* 37–40.

Rogoff, B., & Lave, J. (Eds.). (1984). *Everyday cognition: Its development in social context.* Cambridge, MA: Harvard University Press.

Roring, R. W., Nandagopal, K., & Ericsson, K. A. (in press). Can Parieto-Frontal Integration Theory be extended to account for individual differences in skilled and expert performance in everyday life? *Behavior and Brain Sciences.*

Runco, M. A. (2007). *Creativity theories and themes: Research development, and practice*. Amsterdam; Elsevier.

Shanteau, J., & Stewart, T. R. (1992). Why study expert decision making? Some historical perspectives and comments. *Organizational Behavior and Human Decision Processes, 53,* 95–106.

Shiffrin, R. M. (1996). Laboratory experimentation on the genesis of expertise. In K. A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games* (pp. 337–345). Mahwah, NJ: Erlbaum.

Simon, H. A., & Chase, W. G. (1973). Skill in chess. *American Scientist, 61,* 394–403.

Simonton, D. K. (2004). *Creativity in science: Chance, logic, genius, and zeitgeist.* Cambridge, UK: Cambridge University Press.

Simonton, D. K. (2006). Historiometric methods. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman, R. R. (Eds.). *Cambridge handbook of expertise and expert performance* (pp. 319–335). Cambridge, UK: Cambridge University Press.

Starks, J., & Ericsson, K. A. (Eds.). (2003). Expert performance in sport: Recent advances in research on sport expertise. Champaign, IL: Human Kinetics.

Sternberg, R. J., & Grigorenko, E. L. (Eds.) (2003). *The psychology of* *abilities, competencies and expertise.* Cambridge, UK: Cambridge University Press.

Tetlock, P. E. (2005). *Expert political judgment: How good is it? How can we know?* Princeton, NJ: Princeton University Press.

Tsui, A. B. M. (2003). *Understanding expertise in teaching: Case studies of ESL teachers.* Cambridge, UK: Cambridge University Press.

Tulving, E. (1991). Memory research is not a zero-sum game. *American Psychologist, 46,* 41–42.

van der Maas, H. L. J., & Wagenmakers, E. J. (2005). A psychometric analysis of chess expertise. *American Journal of Psychology, 118,* 29–60.

Vernig, P. M. (2007). From Science to Practice: Bridging the Gap with Translational Research. *APS Observer, 20,* 29–30.

Ward, P., Hodges, N. J., Starkes, J., & Williams, A. M. J. (in press). The road to excellence in soccer: A quasi-longitudinal approach to deliberate practice. *High Ability Studies.*

Ward, P., Hodges, N. J., Williams, A. M., & Starkes, J. (2004). Deliberate practice and expert performance: Defining the path to excellence. In A. M. Williams, & N. J. Hodges (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice* (pp. 231–258). Routledge: London.

Ward, P., &Williams, A. M. (2003). Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. *Journal of Sport and Exercise Psychology, 25,* 93–111.

Weisberg, R. S. (2007). *Creativity.* Hoboken, NJ: Wiley.

Wilding, J. M., & Valentine, E. M. (2006). Exceptional memory. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 539–552). Cambridge, UK: Cambridge University Press.

Williamon, A. (Ed.) (2004). Musical excellence: Strategies and techniques to enhance performance. Oxford, UK: Oxford University Press.

Williams, A. M., & Davids, K. (1995). Declarative knowledge in sport: A by-product of experience or a characteristic of expertise? *Journal of Sport and Exercise Psychology, 17,* 259–275.

Williams, A. M., Davids, K., & Williams, J. G. (1999). *Visual perception and action in sport.* E. & F. N. Spon: London.

Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. *Human Movement Science, 24,* 283–307.

Williams, A. M., & Hodges, N. J. (Eds.). (2004). *Skill Acquisition in sport: Research, theory and practice* (pp. 231–258). Routledge: London.

Williams, A. M., Ward, P., Knowles, J. M., & Smeeton, N. (2002). Perceptual skill in real-world tasks: Training, instruction, and transfer. *Journal of Experimental Psychology: Applied, 8,* 259–270.

Winner, E., & Casey, M. B. (1992). Cognitive profiles of artists. In G. C. Cupchik & J. László, (Eds.), *Emerging visions of the aesthetic process: Psychology, semiology, and philosophy.* (pp. 154–170). New York: Cambridge University Press.

Wolf, T. H. (1973). *Alfred Binet.* Chicago: University of Chicago Press.

Received December 31, 2006
Accepted July 3, 2007 ■