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Recent Advances in Expertise Research: A Commentary on the Contributions to the Special Issue

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SUMMARY

A brief historical background on scientific studies of expert performance describes how the articles published in this special issue relate to recent advances in the study of expertise. This commentary reviews how research on expertise originally focused on testing chess experts' memory as a convenient substitute for studies of actual performance, such as selecting the best move for chess positions. Most of the articles in the special issue illustrate a new trend towards capturing the expert performance with representative tasks in the laboratory and focus on how this superior performance is acquired through training and extended deliberate practice. With these and other advances in our knowledge of how experts acquire their superior skills, the study of expertise is establishing its most important implications for theoretical and applied cognitive psychology. Copyright © 2005 John Wiley & Sons, Ltd.

Some readers of this special issue on 'Recent Advances in the Study of Expertise' may wonder about the theoretical and empirical connections between these studies, such as beginning chess players learning to select chess moves (de Bruin, Rikers, & Schmidt, this issue) and medical experts recalling aspects of briefly-presented descriptions of patients (Rikers, Schmidt, & Moulaert, this issue). The study of expertise covers remarkably diverse domains, such as sports, chess, music, medicine, and the arts and sciences, and examines the entire range of mastery from beginners to world-class performers. The theoretical assumption that unites these diverse empirical phenomena into an integrated field claims that very high levels of achievement in virtually all domains are mediated by mechanisms acquired during an extended period of training and development. In this commentary I will briefly describe developments toward the science of expert performance. As part of this review I will demonstrate how the contributions in this issue address central theoretical issues in theories of expertise, offer new evidence for the structure of expert performance, and suggest new methods and directions for future studies. In some concluding thoughts I will discuss the common goal of all these contributions, namely to outline how general education might benefit from insights on the structure and the acquisition of very high levels of performance.

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BRIEF HISTORICAL BACKGROUND TO THE STUDY OF EXPERTISE

In the 16th century humanists believed that eminent artists and scientists had received divine gifts that set them apart from the rest of us in a qualitative manner (Ericsson & Charness, 1994). The humanists argued that only these individuals possessed the innate capacities required for producing outstanding achievements in the arts and sciences. Later developments in biology and genetics during the 19th century provided plausible mechanisms for the innate transmissions of the unique gifts. For example, Galton (1869/1979) proposed that eminence was associated with physical, heritable differences in the size and structure of brains and nervous systems.

However, during the 20th century several studies started to question the nature of the differences between experts and less accomplished individuals. When scientists began measuring the presumed superior powers of experts' mental speed, basic memory, and intelligence with psychometric tests, they did not find a general superiority: the experts' advantages were restricted to their specific domain of expertise. For example, the superior memory performance of chess experts was constrained to regular chess positions and did not generalize to other types of materials (Djakow, Petrowski, & Rudik, 1927). Not even IQ distinguishes the best chess players (Doll & Mayr, 1987) nor the most successful and creative among artists and scientists (Taylor, 1975).

In a ground-breaking study de Groot (1946/1978) demonstrated the possibility of directly studying the thought processes mediating the highest levels of expert performance under controlled laboratory conditions. He instructed expert and world-class chess players to think aloud while they selected their next move for a series of chess positions taken from unfamiliar games by chess masters. Fundamentally, de Groot (1946/1978) showed that world-class players selected better moves for chess positions than skilled club players and provided initial insights into the processes mediating this difference. His findings on the structure of chess skill led to the first theory of expertise.

SIMON AND CHASE'S ORIGINAL THEORY OF EXPERTISE—PATTERN RECOGNITION AND CHUNKING

Simon and Chase (1973) proposed the first general theory of expertise, and it was based on the human-information processing theory (Newell & Simon, 1972), which assumes that normal, healthy human adults do not differ in terms of basic short-term memory capacity and other fundamental characteristics of elementary cognitive processes. De Groot (1946/1978) reported evidence supporting this assumption even for world-class chess players, namely these elite individuals did not differ from skilled players in terms of the speed of their thoughts or associated basic memory capacities. Skill in playing chess was primarily attributed to prior chess knowledge and extensive chess experience. Simon and Chase (1973) proposed that with extended experience experts acquire a larger number of increasingly complex patterns of chess pieces (chunks) and use these new chunks to retrieve moves (actions) when similar chess positions are encountered during subsequent chess playing (see Gobet, this issue, for a similar description of their original theory). Their theory also argued that to accumulate a sufficiently large collection of chunks with associations in long-term memory (LTM) to win at international chess tournaments required at least ten years of intense engagement in chess playing and other activities in the domain.

EXPERT-NOVICE STUDIES OF MEMORY FOR REPRESENTATIVE STIMULI

Chase and Simon (1973a, 1973b) extended de Groot's (1946/1978) original findings and demonstrated a new paradigm for studying the complex memory representations of experts. They demonstrated that it was possible to identify such complex patterns (chunks of chess pieces) by analysing the structure of immediate recall of briefly presented chess positions. Hence, their theory argued that all players' recall was constrained by the same limited capacity of their short-term memory (STM)—expressed as the same number of retrievable chunks for all levels of chess players. Experts' superior recall for typical chess positions was, therefore, due to the greater complexity (larger number of chess pieces) of chunks due to the increased 'vocabulary' of patterns and chunks previously acquired in LTM. In support of this claim Chase and Simon (1973a, 1973b) found that the memory advantage of expert players was virtually eliminated when they presented scrambled arrangements of chess pieces (see Gobet & Simon, 1998).

The Chase and Simon (1973b) paradigm permitted investigators to study expertise without detailed analyses of the domain-specific processes mediating superior performance, such as selecting the best move for positions. Investigators simply displayed representative stimuli, in their normal and scrambled form, to experts and novices and recorded the accuracy of recall. In most domains information about the objective performance of experts was not available, and investigators defined expertise by social indices and by the length of their professional experience. Numerous studies found that experts had superior memory for representative stimuli, but not scrambled stimuli, compared to novices in a wide range of different domains of expertise (Ericsson & Lehmann, 1996). However, the memory superiority of experts over novices is not without a significant number of exceptions (Ericsson & Lehmann, 1996; Ericsson, Patel, & Kintsch, 2000). One of the most striking exceptions is the 'intermediate effect' in medicine, where advanced medical students (with intermediate expertise) display superior recall of medical cases compared to both medical experts and beginning medical students (novices) (Schmidt & Boshuizen, 1993). Rikers et al. (this issue) contrast immediate memory for brief descriptions of medical cases to assess changes in underlying memory structure of advanced medical students and family doctors with extensive experience. They found no interactions as a function of experience and the family doctors were uniformly faster at accessing all types of information than the medical students. This result is consistent with the classic effects of speed-up with experience, such as the power law (Newell & Rosenbloom, 1981) and frequency of exposure on naming speed (Bates et al., 2003; Zevin & Seidenberg, 2004). However, given that the family practitioners (experts) were not more accurate in their diagnoses than the medical students, these differences probably do not correspond to factors that mediate superior diagnostic performance in medicine. In fact, it is well established that amount of relevant experience in a domain is frequently weakly related to performance, such as effectiveness of treatment of therapy patients, making investments, and other types of 'expert' judgments (Ericsson, 2004). The realization that several of Simon and Chase's theoretical assumptions, such as the inevitable increases in performance due to the gradual accumulation of more complex patterns with experience, may be incorrect led some investigators to challenge this theory as well as the associated paradigm for studying expert-novice differences in memory (Ericsson & Smith, 1991).

CHALLENGES TO THE SIMON AND CHASE (1973) ORIGINAL THEORY OF EXPERTISE

Several of the theoretical assumptions of the original theory of expertise by Simon and Chase (1973) have been challenged. First and most critically, accounting for expertise in terms of chunks and simple pattern-recognition is inadequate for explaining a wide range of phenomena and characteristics of expert performance. In fact, the theory could not account for experts' abilities to anticipate, plan, evaluate, and reason and the associated expansion of effective working memory capacity drawing on long-term working memory (LTWM, Ericsson & Kintsch, 1995). In a proposal to extend the chunking theory Gobet and Simon (1996) proposed the emergence of rapid storage in LTM by the acquisition of templates. In his article Gobet (this issue) describes how the development of templates can account for a wide range of phenomena involving memory and concept formation in the domain of chess as well as in other domains. The template account is based on the extension of computational accounts of chunking and templates toward explaining memory phenomena. In contrast, the LTWM account (Ericsson & Kintsch, 2000; Gobet, 2000a, 2000b) views the development of memory mechanisms as incidental, resulting from adaptations designed to improve performance in the domain of expertise.

If the simple chunking account of expertise by Simon and Chase (1973) is taken as insufficient, serious questions arise concerning the promise of research on immediate memory to understand the structure of performance on representative tasks. In fact, although immediate memory performance often correlates with objective measures of performance, such as success in tournaments and in treatment of medical patients, performance on other standardized tasks, such as selecting moves for chess positions and diagnosing descriptions of medical patients, predicts this objective performance to a substantially higher degree (Ericsson & Kintsch, 2000; Ericsson et al., 2000). Hence, Ericsson and Smith (1991) proposed that we should attempt to identify tasks that capture the essence of expertise in a domain and then study the mechanisms that mediate the superior performance of experts. This approach has been quite successful in a wide range of domains (Ericsson, 2004; Ericsson & Lehmann, 1996). Van Gog, Paas, and Merriënboer (this issue) demonstrate how this general approach can be modified to study the mechanisms that mediate individual differences in finding faults in electric circuits. They examined the structure of eye fixations in two groups that differed in their overall performance for a collection of tasks. Their analysis gave suggestive evidence for differences between the two groups in average length of eye fixations, which seemed to change as the function of the stage of problem solving. Based on my own research I have found that an analysis of the process data, such as eye fixations and verbal protocols, better identifies differences associated with skill and expertise (Ericsson & Simon, 1993), especially for problem solutions of individual participants and experts (Ericsson, Delaney, Weaver, & Mahadevan, 2004). The general approach of using process-tracing methods to identify the mechanisms responsible for the superior performance of skilled participants holds particular promise for the improved design of instruction, assessment and training (Van Gog, Ericsson, Rikers, & Paas, in press).

Finally, Simon and Chase (1973) argued the experts' large body of chunks/patterns and associated knowledge was acquired piece by piece and thus accrued slowly as a direct consequence of increasing amounts of experience. However, the earlier mentioned evidence for very complex acquired mechanisms mediating expert chess performance raises doubts about the sufficiency of a piecemeal acquisition through learning by merely acquiring new and more complex chunks. In fact, research has found only a weak correlation between representative performance in a wide range of domains of expertise and the amount of experience in the corresponding domain, at least beyond the initial period when minimal acceptable proficiency is attained (Ericsson, 2004; Ericsson & Lehmann, 1996). The crucial factor leading to continued improvement and attainment of expert performance is the engagement in special practice activities that allow performers to improve specific aspects of their performance with problem solving and through repetitions with feedback (deliberate practice—Ericsson, Krampe, & Tesch-Römer, 1993). For a wide range of different types of expertise, such as typing, interpreting, medical diagnosis and sports, it is possible to identify deliberate practice activities that allow performers to stretch their performance to a higher level. For example, aspiring chess players spend several hours per day playing through games between chess masters where they try to select the best move for each position—namely, the particular move picked by the masters (Ericsson, 2004; Ericsson et al., 1993). When they fail to select the chess master's move they then analyse and study the position until they discover the reasons for the master's move selection. The paper by Charness, Tuffiash, Krampe, Reingold, and Vasyukova (this issue) extends an earlier classic chapter by Charness, Krampe, and Mayr (1996) and examines retrospective estimates by a large sample of chess players about their training during the development of their skill and expertise. This paper reports the most compelling and detailed evidence for how designed training (deliberate practice) is the crucial factor in developing expert chess performance. I argue that this paper along with other recent papers on the acquisition of expert performance in sport (Côté, Ericsson, & Beamer, in press; Ericsson, 2003a; Ward, Hodges, Williams, & Starkes, 2004) and in music (Ericsson, 2002) demonstrate how retrospective analyses of development support skill-based accounts of individual differences in attained level of expert performance.

However, the necessity of thousands of hours of deliberate practice for attaining expert performance doesn't prove that this training is sufficient. We need to analyse the microstructure of this type of training and demonstrate that additional specific deliberate practice improves particular aspects of the target performance. There are a number of studies examining the detailed structure of experts' deliberate practice in music (Chaffin & Imre, 1997; Nielsen, 1999) and in sports (Deakin & Cobley, 2003; Ericsson, 2003a). There are even experimental studies showing how limited deliberate training to improve on specific aspects of performance can increase performance even among elite individuals, such as athletes competing at the international level (Ericsson, 2003b). Research on implications of the structure of experts' deliberate practice for early skill acquisition and general education is limited in comparison. De Bruin et al. (this issue) report on an experiment with complete beginners in chess, who had never played chess before. Some of the participants in the experimental design were instructed to give judgments of learning (JOL) to induce increased metacognitive awareness—an aspect of self-regulated expert learning. De Bruin et al. were able to induce a reliably higher degree of self-regulation during study in the condition, where participants were forced to give JOLs as well as restudy a minimal number of moves. The induced self-regulation, however, did not lead to increased performance on a representative transfer task, namely selecting superior moves for endgame positions. In fact, requiring the participants to restudy a minimal number of moves improved transfer performance on the endgame tasks regardless of whether JOLs were produced. In their discussion of their results de Bruin et al. emphasize the failure of inducing metacogntive awareness that benefits learning and performance in complete beginners rather than focusing on the reliable effects of forcing the participants to engage in a minimal amount of restudy. Consistent with this latter finding, A. B. H. de Bruin, R. M. J. P. Rikers, and H. G. Schmidt (Poster presented at the Annual Meeting of American Educational Research Association, Chicago, 2003) found in an earlier study that beginners' performance can be enhanced by including a training condition that required participants to select moves with feedback, and had them explain incorrect moves—similar to the structure of deliberate practice in chess. There are several other interesting developments where laboratory investigators have attempted to induce processes evidenced in the execution of performance and caused continued improvements by experts (de Bruin et al., this issue; Ericsson, 2002; Zimmerman, 2002), such as planning, reflection, and evaluation. Berardi-Coletta, Buyer, Dominowski, and Rellinger (1995) isolated the effects of requiring students to explain the solution processes. The discovered effects of self-explanation (Chi, de Leeuw, Chiu, & LaVancher, 1994) have also been successfully replicated under experimental control (Atkinson, Renkl, & Merrill, 2003). Similar improvements on the quality of learning outcomes have also been induced by forcing participants to plan their solutions mentally (Delaney, Ericsson, & Knowles, 2004).

CONCLUSIONS AND FUTURE DIRECTIONS

All the contributions to this issue are motivated by the goal of studying expertise as a means of improving the training of less skilled individuals. Our growing understanding of what aspects distinguish experts from novices should translate into more effective training. Several early studies on expertise were motivated by the goal of extracting the relevant knowledge of the experts. Instead of having each person rediscover knowledge on their own, students could learn the experts' knowledge directly. The difference between having to learn a domain by oneself compared to being told and guided by an expert is dramatic. For example, in the 13th century the famous philosopher Roger Bacon claimed that 'nobody can obtain proficiency in the science of mathematics by the method hitherto known unless he devotes to its study thirty or forty years' (original quote given by Singer, 1958, p. 91). However, most of that mathematical knowledge can today be acquired by adolescents in high school through superior instruction and better organization of the subject matter.

The acquisition of reproducible superior performance on domain-specific tasks goes beyond accumulating knowledge. The development of high levels of skill requires the acquisition of representations that allow efficient control and execution of performance as well as mechanisms that support planning, reasoning and evaluation that mediate further improvement and maintenance of high levels of performance. The requirements for mental mechanisms that simultaneously provide control of the execution of current performance and allow gradual improvement and change toward increased levels of performance impose important theoretical constraints on plausible mechanisms for skilled learning. Deliberate practice activities must be tightly coordinated and focus sequentially on improving one specified aspect of performance at a time (Ericsson, 2002, 2003a). Furthermore, the amount of deliberate practice needed to win at the international level is massive and intimidating (Charness et al., this issue). As we learn more about how training during the development of the best performers is optimized to incrementally improve their performance in traditional domains, such as music and chess, we learn that improving the quality and quantity of deliberate practice for performers reaching the highest levels is a challenging, almost unreachable goal. Instead there is much to learn from how these elite individuals begin training and increase the quality of deliberate practice by acquiring complex mechanisms for controlling, executing and monitoring their performance (Ericsson 2002, 2003a; Zimmerman, 2002). The study of expert and elite performers in music and chess will provide improved insights into the mechanisms for optimal sustained improvement and maintained performance. These insights will not lead to magical fixes or instant dramatic improvements of less skilled learners, but will clarify the need for pre-requisite cognitive skills and knowledge requirements for effective learning and deliberate practice at all the levels of expertise.

The study of expert performers in those traditional domains, where measurement of performance and individual coaching have been employed for centuries, will have implications for training and performance development not just in general education in schools (van Gog et al., in press, this issue), but also for many domains of expertise with less developed training cultures. Recent analyses of many sports show that deliberate practice is much less rigorous and extensive than that observed for training for elite musicians (Ericsson 2003a; Deakin & Cobley, 2003; Ward et al., 2004). Perhaps the most exciting and socially relevant implications for improved training are found in medicine and other professional domains (Ericsson, 2004), where there are limited evaluation and standardized assessment of individual differences in performance and no organized culture with coaching and deliberate practice. Further research on skill acquisition in applied contexts with motivated performers will provide immediate and uncensored feedback. This feedback will help us develop comprehensive theoretical models that can successfully guide performers and their teachers to acquire the complex mechanisms mediating learning and continued improvements of performance.

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