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The study of expertise: Prospects and limits

A Symposium organized by Anders Ericsson and Vimla Patel

During the last twenty years the study of expertise has emerged as one of the major research topics in Cognitive Science. Innovative and diverse research approaches have accumulated a rich body of differences between experts and novices in many different domains of expertise, such as chess, bridge, physics, medicine, writing, music, decision making, computer programming and sports. The majority of the findings suggest similar characteristics of expertise across domains; but some findings, for example, imply that expertise is not always associated with superior performance (cf. expert decision makers) or with superior memory performance (cf. some types of sport, music and medicine). The purpose of this symposium is to provide a state-of-the-art review of contemporary research on expertise to identify methodological issues, theoretical mechanisms and empirical findings generalizing across different domains of expertise.

The paper by Ericsson discusses different research approaches to the study of expertise and adopts the original expertise approach derived from de Groot's and Chase and Simon's pioneering research on chess expertise as the most fruitful framework for the study of expertise. According to this approach, superior real-life performance of experts has first to be captured by specially designed tasks in the laboratory. The superior performance of experts, which can be reliably reproduced in the laboratory, can then be analyzed in terms of superior mediating processes using process tracing and experimental analysis. The focus in this approach on stable expert performance may be viewed as both a strength as well as a limitation of the original expertise approach.

The research findings from analyses of expert performance in chess (Charness), physics (Anzai), medicine (Patel & Groen) and sports (Allard & Starkes) are reviewed and discussed in terms of generalizable concepts and phenomena across the four domains of expertise. Charness focuses on the balance between knowledge and search in selection of the correct actions (e.g., chess moves). Anzai describes the representation of physics problems as captured by the construction of diagrams. Patel and Groen discuss forward reasoning and enhanced recall in medical expertise. Allard and Starkes examine the relation between superior perceptual and memory performance and level of expertise for a wide range of different types of sports. The symposium is concluded with a general discussion by Keith Holyoak.

Presenters: Anders Ericsson
Neil Charness
Yucho Anzai
Vimla Patel
Fran Allard
Discussant: Keith Holyoak

**Approaches to the empirical study of expertise:
Some general issues and considerations**

**K. Anders Ericsson
University of Colorado at Boulder**

With the growing interest in research on expertise, a diverse set of research approaches has emerged. Experts are often identified using social criteria and the amount of experience and the level of performance of these experts is then compared to those of novices and less experienced subjects on various tasks. In this paper, we argue that the success of the pioneering research on chess was due to the satisfaction of a number of additional constraints. The primary focus of the pioneering research on expertise in chess was to study stable superior performance in real life expert activities. Hence the first step in such a study involves an analysis of that real life performance to identify a set of tasks which captures reliably the superior performance of experts in the laboratory. Once the superior performance of experts has been reliably reproduced in the laboratory, examination of the critical mediating processes responsible for the superior performance can be made using standard methods of process tracing and experimental analysis. When the critical processes have been identified, the issue of how these processes can be acquired during extended practice is raised. Theoretical analyses of learning and skill acquisition are explored. Most importantly, empirical studies of the acquisition of the critical processes can be made by cross-sectional comparisons of subjects with differing amounts of expertise and experience, by studies of extended training on the target tasks and by a careful analysis of the real-life practice activities designed to maximize improvement of performance.

Skill in Chess: The Balance Between Knowledge and Search

**Neil Charness
University of Waterloo**

Two strikingly different routes have been taken to achieve high levels of chess skill. Programs such as Deep Thought use extensive search (about 720,000 positions examined/second) to decide on the best move, with little knowledge of chess beyond center control, mobility, and piece balance. Human grandmasters rely on extensive knowledge of chess openings, middlegame plans, and techniques for playing endings to enable extremely modest search (10 positions/minute) to uncover the best move. I will examine the trade-offs between knowledge and search in chess and focus on the knowledge base that humans rely on. Questions to be addressed are: 1) How much knowledge accrues to humans via tournament play versus study? 2) What effect have national training programs had on the development of skilled players? 3) How do the different forms of chess (blitz, tournament, postal) depend on search versus knowledge? 4) How has knowledge accumulation affected peak levels of chess performance by Grandmasters over the past century? 5) What role does aging play in the inverted U-shaped life-time chess performance function?

Learning How to Draw Diagrams for Physics Expertise

**Yuichiro Anzai
Keio University**

Experts in physics draw diagrams that include appropriate information for solving problems. While the diagrams drawn by novice learners are usually not well suited for problem solving. Why does this difference in expertise occur? How does a novice acquire the knowledge of how to draw diagrams? I try to answer these questions by providing a cognitive theory that explains the process of learning to draw physics diagrams. In short, the theory insists that the two kinds of knowledge, for how to draw diagrams and how to make inferences in problem solving, are acquired through the process of utilizing each other. [That is, a more sophisticated inference strategy for problem solving, once acquired, aids the acquisition of a more elegant procedure for representing problems with diagrams and vice versa.] Thus, the two processes, learning inferencing and drawing, may bootstrap to make expertise grow. The theory was developed based on observations from a longitudinal study of one novice subject acquiring expertise.

The generality of medical expertise:

A critical look

**Vimla L. Patel and Guy J. Groen
McGill University**

Two fundamental empirical findings in research on expert-novice comparisons have been the phenomena of enhanced recall and of forward reasoning. The first refers to the fact that experts have superior skills in recognizing patterns in their domain of expertise. The second pertains to the findings that, in solving routine problems in their domains, expert problem solvers tend to work forward from the given information to the unknown. Our main purpose is to re-evaluate, in the context of medical expertise, the assumption that there is a close relationship between these two phenomena, in the context of expert-novice comparisons of clinical reasoning in medicine.

We present evidence to show that recall of clinical information by medical specialists is unrelated to pure diagnostic accuracy. In contrast, pure forward reasoning is closely related to diagnostic accuracy. It is shown that this pattern is a function of the specific relevant knowledge possessed by the physicians. It is also shown that it is dependent on the structure of the clinical case since the presence of "loose-ends" unrelated to the main diagnosis is frequently accompanied by backward reasoning.

The absence of recall differences in experts is contrasted with the recall of intermediates and novices, where strong recall differences are found. This leads to a suggestion that there are two kinds of expertise; generic expertise, in which ways of

representing medical knowledge are acquired, and specific expertise, in which no fundamental representational changes are taking place. The possibility that the acquisition of generic expertise is non-monotonic is also discussed.

Expertise in Sport
Fran Allard, University of Waterloo
and
Jan Starkes, McMaster University

Success in sport involves expertise in both knowledge of the domain and performance of relevant motor skills. For closed motor skills such as dance or figure skating, the skilled individual must be able to remember long sequences of movement elements to perform a role or routine. For open skills such as basketball and football, the ability to learn offensive and defensive patterns is essential for all team members.

Studies will be reviewed to illustrate the superior recall performance shown by expert ballet dancers and figure skaters over less skilled performers when recalling choreographed dance or skating sequences. As in many other skill domains, the experts' advantage evaporates when the sequences presented for recall are randomly ordered strings of the same set of items.

Skilled basketball players show a similar recall superiority for the recall of schematic diagrams of basketball plays, showing that sensitivity to the structure of the domain cuts across both open and closed sport skills. One exception to the finding of the importance of pattern for sport experts occurs for volleyball. Skilled volleyball players do not show differential recall accuracy for either schematic play recall or for recall of the position of players on slides of real volleyball games. Expert volleyball players are much faster than less skilled players at detecting the presence of a ball in briefly presented slides of volleyball games, showing rapid search to be an important component to skill in this game.

The relationship between cognitive skill and performance skill will also be considered in this presentation.