#29A

Chess: Contributions to the Understanding of Human Cognition

Sarah E. Goldin
Carnegie-Mellon University

The chessmaster's extraordinary performance has long fascinated the psychologist as well as the layman. Consider his phenomenal abilities: he announces a forced mate ten moves in advance; blindfolded, he plays dozens of games simultaneously; without hesitation, he recapitulates the main lines and variations of hundreds of games. Surely, these feats imply phenomenal memory capacity, prodigious reasoning ability and vast calculational power. Or do they? To the psychologist, this question represents a challenge and an opportunity. The challenge is to explain the amazing performance of the chess master in terms of the known properties, capacities and limitations of human thought. The opportunity is to discover new truths about the organization and content of human cognitive processes.

Psychological experimentation on chess began to make real headway in the thirties, with the work of the Dutch scientist Adrian de Groot. De Groot subjected players from grandmaster to amateur strength to an extensive battery of tests tapping both chess and non-chess skills. His results were startling: there were almost no differences between masters and weaker players. Masters did not excel in general memory capacity, in spatial reasoning ability, in mathematical ability, or in overall intelligence. Whatever accounted for chess skill was clearly specific to chess. Even more surprisingly, masters and non-masters did not show great differences in their patterns of analysis while choosing a move. They considered roughly the same number of variations as the weaker players, explored each line to more or less the same depth, and followed the same sort of "progressive deepening" strategy- cyclically reconsidering each candidate move in turn and analyzing it more extensively. Although the patterns of the masters' analysis were similar to less experienced players', however, their results were not. Masters almost always found the correct move, while the other subjects seldom did.

One other task differentiated strongly between skill levels: immediate recall. After 5 to 10 seconds of observation, masters and weaker players were asked to reconstruct a middlegame position from memory. Here master level players performed nearly perfectly; they would correctly recall perhaps 28 or 29 pieces of a 30 piece position, compared to amateurs, who could remember only 8 or 10 pieces. The masters' comments in this task suggested that they recognized sub-parts of the stimulus positions and that this recognition was responsible for their accurate reconstruction. They might never have seen the particular stimulus position before, but they were familiar with its components.

The message of de Groot's work is clear: chess skill does not depend on prodigious intellectual endowments, but, quite simply, on extensive knowledge. The organization of thought processes remains more or less constant across skill; only the content differs. It also seems that chess masters do not possess abilities that are in any way abnormal, uncanny or bizarre. They are simply dedicated human beings who by conscientious study have learned to make the most of their cognitive capabilities in a special domain.

For the psychologist, the chess master has become the paradigmatic case of skilled performance. By studying problem-solving and memory in chess, we have gained a great deal of knowledge about the psychological meaning of skill.

The study of chess as problem-solving was pioneered by some of my colleagues at Carnegie-Mellon University. Chess players of varying levels of skill were instructed to "think aloud" while choosing the best move in a quiet middlegame position. First of all, it was found analysis was not exhaustive; players usually selected only two or three moves for further exploration. The choice of candidate moves was clearly a function of chess knowledge and experience. Secondly, the analysis process at all levels of skill showed clear evidence of the "progressive deepening strategy" first detected by de Groot. Players tended to analyze the variations stemming from each candidate move several times, each time pushing deeper or examining new branches on the analysis tree. Apparently, skilled players adopt a strategy that makes as few demands as possible on their memories. From other research, we know that the small capacity of immediate memory is the most serious obstacle to performance in complex tasks. The progressive deepening strtegy allows players to deal with each variation as several short series of moves, each summarized by an interim evaluation, rather than as a single extended sequence that would exceed the limits on short term recall.

One recently-developed technique for charting the course of thought is the recording of eye movements. A special apparatus indicates exactly where the chess player is looking from moment to moment as he tries to choose his next move. On the whole, the sequence in which pieces on the board are visually examined corresponds quite well with the verbal descriptions of analysis. However, more moves are inspected visually than are reported verbally. Furthermore, the eye movement records suggest a very general strategy that is used to find possible moves. This method, known as "means-ends analysis", involves the establishment of a goal and then a search for a way to achieve it. For example, the goal of saving an attacked piece might be met by moving the piece, defending it, or counter-attacking. In the course of search, subgoals may be developed. The player in this example may set himself the subgoal of defending the piece, then start seeking a feasible move that will accomplish this more specific purpose. The patterns of eye movement activity show the details of goal establishment and move search in a fairly straightforward way.

The results of research on problem solving in chess have general psychological interest. The progressive deepening strategy appears to be an adaptation to fundamental limitations on human attentional and memorial capacities. Means-ends analysis has proved to be a basic technique used in human problem solving, in domains ranging from logic theorem proving to architectural design. Studying the verbal records from the move-choosing task contributed to the development of the General Problem Solver, a landmark computer program able to solve almost any well-defined problem, given a description of its elements and top-level goal. Clearly, both the challenge and the opportunity of chess research have been fulfilled in these studies of cognitive organization.

Investigations into chess perception and memory have proved equally fruitful. In the 1907 volume of the American Journal of Psychology, Alfred Cleveland asserted that, "Progress in chess, like progress in abstract thinking of any kind, consists in the formation of an increasing symbolism which permits the manipulation of larger and larger complexes." Until recently, there has been little solid evidence to substantiate his claim. In 1973, colleagues at Carnegie-Mellon demonstrated the truth of this statement in the context of a chess memory experiment. Chessplayers recalling a position after a brief presentation seemed to process the position as a series of "chunks", configurations or patterns of pieces linked by relations of proximity, color and mutual defense. The contents of these chunks could be assessed by measuring the pauses between pieces during reconstruction of the position. Pauses between chunks are almost twice as long as within-chunk pauses. Both Masters and weaker players produce about the same number of chunks for a given position, usually 7 or 8. However, the masters' chunks contain 3 to 5 pieces per chunk, compared to a beginner, whose chunks average only one or two pieces in size. Thus a master can recall more of a position than a weaker player, even though he has basically the same memory capacity in terms of chunks, because he can recognize and process larger units. The skill difference lies in the amount of knowledge and in how it is organized, not in the nature of the thought processes themselves.

This "chunking" result seems to be a common characteristic of skilled performance in many domains. Experts in other games such as bridge and Go appear to process material in larger units than novices; the same is true for practiced observers of sports events, skilled architects reading blueprints and skilled readers. I have informally studied my own developing ability to form chess chunks. Over the course of a year, I studied chess an average of one hour daily and took a battery of memory tests once a week. My skill level increased by about 300 rating points; at the same time, my recall performance jumped from about 25% to about 55%. The average size of the familiar patterns I could recognize increased concurrently, from about 2.5 to about 3.5 pieces per chunk.

Other research I have performed examines a different issue in chess memory, the importance of meaning. Back in 1893, Alfred Binet suggested that "the crucial factor in a players' memorization of a series of moves or a particular position is the ability to endow those moves or that position with a precise meaning." In my experiments, chessplayers of varying degrees of skill were given either a meaningful chess task- analyzing a set of positions- or a meaningless task, simply copying them from a diagram to the board. Both tasks took the same amount of time. After performing these meaningful or meaningless tasks, all players were given an unexpected recognition memory test. Memory for the original positions was more accurate when those positions had been procesed in a meaningful way rather than merely copied.

These results highlight the fact that chess knowledge includes more than just a repertoire of familiar piece patterns. The conclusion may seem obvious to anyone who plays chess; to quote Binet once again, " chess memory is not a memory of sensations, but a memory of ideas". The primacy of meaning has been a theme running through psychology ever since it was discovered that memory for real words is much better than memory for nonsense syllables. The results of my chess research place chess squarely in the mainstream of cognitive theory. They also suggest once again that chess masters are ordinary human beings taking maximum advantage of the built-in properties of human memory.

The study of chess as a cognitive activity has obvious interest to the psycholog8gist. What are the implications of chess research for the layman? First of all, it appears that studying chess will NOT generally improve the intellect, as has been claimed. Evidence suggests that, within the range of normal intellectual endowments, chess skill is independent of logical ability, mathematical talent, spatial reasoning skills, and other cognitive faculties. There may indeed be motivational factors that make chess a useful pedagogical tool; certainly, serious chess scholarship demands discipline, persistence, organization and sustained concentration. All of these qualities may transfer to other areas of life. It is simply not the case, however, that chess study will increase cognitive capabilities in other domains.

On the other hand, studying chess WILL produce systematic increases in chess skill. Once again, motivational variables complicate this issue, but all other things being equal, experience is the best predictor of ability in chess. Most evidence contradicts Binet's provocative claim that "one may ATTAIN average standing, but one is BORN a chess master." This suggests that the intellectual and aesthetic delights of chess are accessible to anyone willing to work for them. Morphy and Fischer represent prodigies of motivation rather than mentality. Chess may be known as the game of kings, but psychological investigations suggest that, all in all, it is a fundamentally democratic pastime.

Finally, psychology has redeemed the chessmaster from the domain of the freak, the myth or the madman. In order to achieve mastership in chess, one must be conscientious, dedicated and disciplined. Above all, one must love the game. These are very healthy, very human qualities. In the case of chess, science has enriched our humanity rather than diminished it, by enabling us to understand how ordinary humans can function to perform extraordinary feats. The value of a psychological approach to chess is summed up nicely by Herbert Simon, a chessplayer himself and one of the foremost researchers on chess: "The aesthetics of natural science [...] is at one with the aesthetics of music and painting. Both inhere in the discovery of a partially concealed pattern."

Bibliography

Binet, A. Mnemonic virtuosity: a study of chess-players. Genetic Psychology Monographs, 1966, 74, 127-162. (Originally published in Revue de Deux Mondes, 1893, 117, 826-859, as "Les Grandes Memoires: Resume d'une Enquete sur les Joueurs d' Echecs").

- A fascinating, "naive psychologists" view of chess memory and skill; especially interesting is Binet's description of chess culture in the late 1800's, e.g. the distinction between amateur players and professional cafe hustlers.

Charness, N. Human chess skill. In P. Frey (Ed.), Chess skill in man and machine. New York: Springer-Verlag, 1977.

- A fine summary of most of the modern chess research. The entire book may be useful, especially to those interested in computer chess.

Chase, W.G. and Simon, H.A. The mind's eye in chess. In W.G. Chase (Ed.), Visual information processing. New York: Academic, 1973. (a)

Chase, W.G. and Simon, H.A. Perception in chess. Cognitive Psychology, 1973 (b), 4, 55-81.

- These are the two classic articles on chess perception and memory, detailing the procedures for discovering the content of "chunks" and the basic position concerning the knowledge dependence of chess skill.

Cleveland, A.A. The psychology of chess and learning to play it. American Journal of Psychology, 1907, 28, 269-308.

- A surprisingly modern view of chess psychology. His description of the learning process, while subjective, seems to me to be quite accurate (from my own experience).

de Groot, A.D. Thought and choice in chess. The Hague: Mouton, 1965.

- The first work to demonstrate the chess-specific nature of chess skills.

de Groot, A.D. Perception and memory versus thought: some old ideas and recent findings. In B. Kleinmuntz, (Ed.), Problem solving: research, method and theory. New York: Wiley, 1966.

- A summary of the first deGroot reference, with an emphasis on the problem solving and analysis aspects of chess.

Goldin, S.E. Effects of orienting tasks on recognition memory for chess positions. American Journal of Psychology, 1978, in press.

FOOTNOTES

2

1. Spatial Aptitude, called "visualization" by Claparede, which essentially relates to so-called practical intelligence. Spatial representation is the ability to perceive relations in various arrangements, returned figures for example (1).

2. Numerical Aptitude, which is to ability to work on figures or numbers and to solve simple quantitative problems rapidly and precisely. We should note the positive and significant correlations to the numerical aptitude test of the PMA and Test 2, numerical aptitude, of GATB. These 2 tests are very similar; both tests relate to monitoring the exactitude of certain arithamatic calculations. Test 6 of GATB, which measures numerical aptitude with greater participation of reasoning, does not significantly correlate with the results in chess.

3. Administrative Ability, which is the aptitude to perceive a pertinent detail in verbal material put on the board, the ability to observe differences in copies, to collate words or names, and to avoid errors in perception in arithematic calculations (2).

4. Clerical Work, or rather the aptitudes brought into play in this work: precision in perception and visual memory as well as rapidity in execution.