ELSEVIER

Cognitive Science 27 (2003) 637–648

COGNITIVE SCIENCE

http://www.elsevier.com/locate/cogsci

Visualization, pattern recognition, and forward search: effects of playing speed and sight of the position on grandmaster chess errors

Christopher F. Chabris [a], Eliot S. Hearst [b,*]

[a] *Harvard University, Cambridge, MA, USA*
[b] *Department of Psychology, College of Social and Behavioral Sciences, University of Arizona, P.O. Box 210068, Tucson, AZ 85721-0068, USA*

Received 27 July 2002; received in revised form 6 December 2002; accepted 27 February 2003

Abstract

A new approach examined two aspects of chess skill, long a popular topic in cognitive science. A powerful computer-chess program calculated the number and magnitude of blunders made by the same 23 grandmasters in hundreds of serious games of slow ("classical") chess, regular "rapid" chess, and rapid "blindfold" chess, in which opponents transmit moves without ever seeing the actual position. Rapid chess led to substantially more and larger blunders than classical chess. Perhaps more surprisingly, the frequency and magnitude of blunders did not differ in rapid versus blindfold play, despite the additional memory and visualization load imposed by the latter. We discuss the involvement of various cognitive processes in human problem-solving and expertise, especially with respect to chess. Prior opposing views about the basis of general chess skill have emphasized the dominance of either (a) swift pattern recognition or (b) analyzing ahead, but both seem important and the controversy appears currently unresolvable and perhaps fruitless.

Keywords: Problem-solving; Decision making; Attention; Expertise; Imagery-visualization; Pattern recognition

* Corresponding author. Tel.: +1-520-299-6779.
E-mail address: ehearst@u.arizona.edu (E.S. Hearst).

0364-0213/03/$ – see front matter © 2003 Cognitive Science Society, Inc. All rights reserved.
doi:10.1016/S0364-0213(03)00032-6

1. Introduction

For many years the study of chess skill has been a research focus of cognitive psychologists interested in memory, problem-solving, and expertise (see, e.g., Charness, 1992; Chase & Simon, 1973; de Groot, 1946, 1965/1978; de Groot & Gobet, 1996; Holding, 1985; Reingold, Charness, Pomplun, & Stampe, 2001; Saariluoma, 1995; Simon & Chase, 1973). One controversial issue has concerned the question of whether (a) fast recognition of patterns or (b) detailed analysis and evaluation of different possible move sequences are relatively more important in accounting for the abilities of a skilled player. Gobet and Simon (1996) presented data to support their view that pattern recognition is much more important, because when Gary Kasparov had to play chess fairly rapidly (an average of less than a minute per move) in timed simultaneous-chess exhibitions against masters, the rated quality of his play did not suffer greatly, compared to that in serious, slow tournaments (an average of about 3 min per move). The international ELO system (see ahead) provided an objective method of calculating ratings.

Gobet and Simon concluded that chess skill, for world-class players at least, does not deteriorate much when thinking time is substantially reduced. Advocates of this fairly extreme view have proposed that "recognition, by allowing knowledge to be accessed rapidly, allows the slower look-ahead search to be greatly abridged or even dispensed with entirely without much loss in quality of play" (Gobet & Simon, p. 53).

This inference is similar to that suggested by the results of Calderwood, Klein, and Crandall (1988), who compared tournament games allowing an average decision time of about 135 s per move with fast games allowing an average decision time of about 6 s per move. They found little or no difference in the subjectively rated quality of moves between these two conditions in the play of three masters. Two grandmasters rated the moves blindly.

On the other hand, Holding and coworkers (see Holding, 1985) offered data and arguments in support of their fairly extreme view that search and evaluation of various potential move sequences (greatly emphasized in computer chess programs) are much more important than pattern recognition (hardly present in any computer programs). "Thinking ahead, in all its complexity, defines skill at chess" was the final sentence in Holding's book (p. 256).

This question reflects one of the two major goals of the work reported here. We compared a very large sample of actual grandmaster tournament games played under "rapid" conditions (approximately 25–30 min for each player for all the moves in a game, usually about 40–50 moves for each player, thus averaging less than 1 min per move) with a large sample of games played by the same opponents under standard "slow" tournament conditions (averaging 3 min per move, usually at 40 moves in 2 h for each player), approximately the same time values that Gobet and Simon compared in their analysis of Kasparov's play. We used a powerful chess computer program to assess the number and magnitude of errors under each condition. According to arguments of workers like Gobet and Simon an appreciably larger number and magnitude of errors in the fast games would presumably question their views about the relative importance of recognitional versus calculational processes in chess skill. Computer-defined blunders or mistakes may yield data revealing much more about chess expertise than the use of subjective judgments of move quality (as in Calderwood et al., 1988), or the examination of performance ratings for one player, a world champion, playing simultaneously against substantially weaker masters in non-tournament play (as in Gobet & Simon, 1996).

The other major goal of our research examines a factor that for more than a century has been neglected in the psychological study of chess and most other expert skills that involve spatial abilities: the role of mental imagery and visualization. Many cognitive psychologists are not even familiar with Alfred Binet's (1893, 1894) monumental work on imagery and mental representations in players who can play chess quite well without sight of the actual board ("blindfolded"). Examples of this skill can be traced back to the 8th century AD, not long after a game that resembles the modern version of chess was first devised. Binet was particularly interested in players who could play 8–10 blindfold games simultaneously, but some masters of the 20th century later successfully played 30–45 simultaneous blindfold games, which is a great feat of memory and expertise.

Be that as it may, over the years many masters have claimed that they can play a single game of blindfold chess as well or better than a regular game. Various masters often shut their eyes or look at the ceiling while choosing a move in a standard tournament game; they state that the actual sight of the board and pieces can interfere with their analysis. Masters frequently argue about move possibilities with each other while, say, eating dinner or taking a walk together—when no actual chessboard is present. These remarks could make one wonder about the value of the highly popular use of eye-movement studies in analyzing the chess skill of masters. Hearst and Knott (2003) discuss many historical and psychological aspects of blindfold play, besides presenting biographical material and information about the visuo-memorial techniques reported by its most successful players. They also analyze details of a database they established, which contains hundreds of games played without sight of the board by experts at that type of chess, especially in the 19th and 20th centuries. Some grandmasters even say visualization is the key to success in regular chess. And yet in the past century very few psychological studies have examined this factor or even studied blindfold chess (but see Bachmann & Oit, 1992; Church & Church, 1983; Ericsson & Staszewski, 1989; Milojkovic, 1982; Saariluoma, 1991; Saariluoma & Kalakoski, 1997, 1998, for some articles related to imagery and chess).

We are fortunate that since 1993 a tournament has been held every year in Monaco, where some of the world's best players play two games against each other under the same rapid time limit, one game with sight of the board and the other without. Using a powerful chess computer program and a complete database of all master tournament games played in recent years, we could establish objective criteria for assessing the number and magnitude of blunders in each type of chess. Furthermore, with respect to the first research goal mentioned above, we could compare the rapid games played with sight of the board in the Monaco tourneys with games played with sight of the board between the same opponents at a much slower speed in regular tournaments around the world. Do grandmasters make substantially fewer and less serious errors in slow chess versus fast chess?

This report presents results from what is essentially a natural experiment, possessing a high degree of ecological validity, in which many important factors were held relatively constant because of the structure of the tournaments involved. Though not obtained in a laboratory, the data come from controlled settings that were arranged in a similar way to those of a standard psychological experiment.

2. Method

2.1. Participants

Twenty-three chess grandmasters (20 men and 3 women, ranging in age from 16 (Judit Polgar in 1993) to 63 (Victor Korchnoi in 1994)) provided the results that we analyzed. Among these players were all the recognized world champions and their official challengers from 1974 to 1998, except for Gary Kasparov, and many of the other top-ranked players in the world. Their international (ELO) chess ratings, based on probability models for paired comparisons originally developed by psychometricians and providing a fairly precise and mathematically sound measure of chess skill (see Batchelder & Bershad, 1979; Elo, 1986; Glickman, 1995), ranged from 2530 to 2790 with a mean of 2666. An individual's rating fluctuated somewhat from year to year. At any given time there are usually no more than about 100 active players in the world whose ratings exceed 2600 and only about 30–40 above 2650.

2.2. Setting and rules

We analyzed results in the six Monaco events from 1993 to 1998, each of which included 12 grandmasters. Some players participated in all six tourneys and some in only one to five of them. In one of the games ("blindfold," without sight of the actual position) both players could see only an empty chessboard projected on the computer monitor in front of them, along with the most recent move that their opponent had typed into their linked computers. In the other game ("rapid," with sight of the actual position) both players faced each other across a regular chessboard.

The time limit was equated for both types of games: Each player was allotted 25 min for the entire game, with a bonus of 10 s for each move made in the rapid game and 20 s in the blindfold game (to take into account the fact that in the blindfold game a player also needed about 10 s to type in his or her move and check it for typographical errors before entering it on the computer keyboard). A player forfeited the game if he or she overstepped this time limit (not uncommon). If an illegal move was made, the player lost time replacing it with a legal move.

In three of the six Monaco tourneys the blindfold game between two players was played first, whereas in the other three tourneys the rapid game was played first, with an interval of about 1–2 h between games. The two games between specific individuals were the only games they played on that day. Players with the white pieces (moving first) in the first game had black in the second, and determination of color in the first game and the order of opponents in the entire tournament was decided by lot before it began [as is always done in regular, all-play-all ("round-robin") chess events]. This standard pairing system equalizes the number and sequence of first games with white or black for each player as much as possible. Readers will recognize that many potentially important factors were well-controlled in this setting, as if it were an actual experiment.

To allow a comparison of the relatively fast sighted games at Monaco with normal, slower tournament games ("classical"), we identified for each pair of opponents the most recent game they had played each other under sighted, slow conditions (usually 40 moves in 2 h, an average of 3 min a move). We excluded games ending quickly, in fewer than 20 moves (most of these were drawn games, with both players being satisfied with a half-point each, often because of their current standing in the tourney or because of the belief they needed a rest day). In 40 cases no matching game between two opponents was found in the chess database, probably because they had not played each other outside of Monaco (in a recent important tournament, at least). For these 40 cases we substituted a game played between two other players who competed at Monaco from 1993 to 1998, but not in the same year so that they did not face each other there. We accumulated 396 such "classical," slow games to match the total 396 blindfold and 396 rapid games played at Monaco during those years. The game scores for all three conditions (blindfold, rapid, and classical) were obtained from the ChessBase 7 software package (Hamburg, Germany).

All the actual current positions in the Monaco tourneys, blindfold or rapid, could be seen by the audience on large computerized boards that the players in a roped-off enclosure in front of the audience obviously could not view themselves. Spectators especially enjoy the blindfold games for which onlookers can physically see the actual position and the players cannot.

2.3. Scoring of blunders

To identify all the major blunders made in our set of 1,188 games we processed them by means of the game-analysis facility of the Fritz 5 chessplaying program (ChessBase, Hamburg, Germany) running on a Dell Dimension 233 MHz Pentium II desktop computer system. The Fritz program, with its occasional improvements, has long been one of the world's strongest commercially available microcomputer programs, according to rating lists from various sources. It has won many games from grandmasters. Because chess computers are at their worst in situations involving subtle distinctions and long-range judgments, we used a high threshold for considering a suboptimal move a "blunder," in order to minimize the rate of false positives. The program analyzed every move in the 1,188 games with a nominal 10-ply exhaustive search (i.e., five moves ahead by each player, with a deeper search if an unclear or unstable position was reached after 10 ply), and reported as "candidate blunders" all cases in which the actual move played was evaluated as at least 1.5 pawns worse than the program's choice for the best move. Whether the blunder was actually exploited by opponents was irrelevant in this analysis. The 1.5-pawn criterion was not chosen arbitrarily; an advantage of this size is generally believed by computer chess researchers to be sufficient to win a game, i.e., it is the presumed threshold beyond which a game is theoretically won (see, e.g., Hartmann, 1989).

However, to further refine our set of blunders, we used a conservative criterion to exclude all errors that did not alter the probable outcome of the game. That is, if the same side retained a prior advantage of at least 3.0 pawns even after a blunder, the error was excluded. The remaining set was considered to include only "true blunders."

3. Results

Table 1 displays the numerical results. Of the 1,188 games analyzed, there were 1,123 candidate blunders, of which 719 were true blunders. Broken down by game type there were

Table 1
Measures used to compare grandmaster blunders under three kinds of playing conditions: classical, rapid, and blindfold

Condition	Games[a]	Moves[b]	CB[c]	TB[d]	TB_{EXP}[e]	TB/KM[f]	B_{MEAN}[g]	B_{SE}[h]
Classical	396	35,036	252	176	228.64	5.02	2.66	0.11
Rapid	396	38,816	447	266	253.34	6.85	3.15	0.13
Blindfold	396	36,312	424	277	236.98	7.63	3.08	0.12
Total/mean	1,188	110,164	1,123	719	718.96	6.50	2.96	0.12

[a] Total games in database played under each condition.
[b] Total moves played by both players under each condition.
[c] Candidate blunders (see text).
[d] True blunders (see text).
[e] True blunders expected in each condition assuming that true blunders were distributed equally among conditions according to the total moves in games played in each condition.
[f] True blunders per thousand moves.
[g] Average magnitude, in pawn units, of the true blunders in each condition (after removing blunders that allowed a forced checkmate, which have an infinite magnitude: There were 7 such cases in the classical condition, 14 in the rapid condition, and 10 in the blindfold condition).
[h] Standard error of B_{MEAN}.

176 true blunders in "classical," slow games, 266 in "rapid" games (with sight of the board), and 277 in "blindfold-rapid games (without sight of the board). To examine whether blunders were more frequent in rapid games with sight of the board than in slower, classical games with sight of the board—one of the two major goals of this study—we divided the total number of true blunders in each condition by the total number of moves played in the games in that condition. Grandmasters made 5.02 blunders per 1,000 moves in classical games and 6.85 blunders per 1,000 moves in rapid games (an increase of 36.5%). They also made 7.63 blunders per 1,000 moves in the blindfold games (Table 1).

To assess the statistical significance of the blunder-frequency differences, we calculated the expected number of true blunders in each condition under the null hypothesis that the 719 blunders would be equally distributed among conditions in proportion to the total number of moves played in each condition (see Table 1). The frequency of blunders differed significantly among conditions, $\chi^2(2) = 19.5$, $p < .001$. Individual comparisons showed that the differences between classical and rapid games, as well as between classical and blindfold games, were also significant, $\chi^2(1) = 10.3$, $p = .001$, and $\chi^2(1) = 19.0$, $p < .001$, respectively. However, the difference between rapid and blindfold games was not significant, $\chi^2(1) = 1.6$, $p > .20$.

Furthermore, the magnitudes of the blunders made in each condition differed, as shown in Table 1: the average magnitude of a blunder was 2.66, 3.15, and 3.08 pawn-units for the classical, rapid, and blindfold conditions, respectively. Blunders were less severe under classical conditions than under rapid conditions, $t(419) = 2.7$, $p < .01$, or than under blindfold conditions, $t(434) = 2.4$, $p < .02$. Once again, the difference between rapid and blindfold games was insignificant, $t(517) = 0.4$, with the average blunder magnitude in blindfold games actually being slightly lower than in the rapid games.

We also examined the results when much more flagrant criteria for a true blunder are used: equivalent to the loss of at least 3, 6, or 9 pawns, instead of the 1.5-pawn criterion used previously. All the above differences were maintained (for the 3-pawn criterion: 100, 112, and 47 blunders; for the 6-pawn criterion: 33, 35, and 12 blunders; for the 9-pawn criterion: 18, 24, and 8 blunders, respectively for the blindfold, rapid, and classical conditions).

Each of the χ^2 comparisons for the 3-pawn criterion, calculated taking into account the number of moves in each condition (as for the 1.5-pawn criterion above), was significant beyond the .001 level, except for an insignificant rapid versus blindfold difference; the overall $\chi^2(2)$ was 22.4, the $\chi^2(1)$ for classical versus rapid was 20.4, for classical versus blindfold 17.2, and for rapid versus blindfold 0.1. Similarly, all the χ^2 comparisons for the 6-pawn criterion were significant beyond the .01 level, except for an insignificant rapid versus blindfold difference; the overall $\chi^2(2)$ was 10.4, the $\chi^2(1)$ for classical versus rapid was 9.1, for classical versus blindfold 9.1, and for rapid versus blindfold 0.1. The differences for the 9-pawn criterion followed the same pattern; the overall $\chi^2(2)$ was 6.4, $p < .05$, the $\chi^2(1)$ for classical versus rapid was 6.5, $p = .01$, for classical versus blindfold 3.5, $p = .06$, and for rapid versus blindfold 0.5, ns.

Thus, the two conditions in which chess was played relatively quickly (whether corrected for total number of moves or not) produced more than twice the number of really big blunders (3-, 6-, and 9-pawn) than did the slow, classical condition. Despite the consistent lack of significant differences between the blindfold and rapid groups, it is interesting that the blindfold condition produced fewer mistakes than the rapid condition. This point is noteworthy because of the fact that a player in the blindfold condition could accidentally type in an unintended but legal move, thereby making an inadvertent, big mistake—something that could not happen for the other two arrangements.

In terms of the two major goals of this research, the outcomes were that grandmasters made substantially fewer and smaller mistakes when they had additional time during a sighted game, but there was no significant difference with respect to number and magnitude of mistakes when they played rapidly, either with or without sight of the board. According to our measures, the additional memory and visualization load imposed by blindfold play did not lead to a deterioration of grandmaster performance.

4. Discussion

No one strongly disputes the point that recognition of patterns, chunks, "clues," or templates—as well as forward search—both constitute essential parts of the skilled chessplayer's arsenal of weapons. The open question has been whether, of all the moves that quickly present themselves as likely candidates for the best move, the detailed analysis and evaluation of their consequences is as crucial and perhaps of even greater importance than initial recognition processes in accounting for a grandmaster's superior level of performance. Work done mainly within Simon's group (see especially Gobet & Simon, 1996) led them to conclude that because a great decrease in time to think during simultaneous-exhibition play against a total of 56 considerably weaker masters in nine separate displays apparently did not lead to much loss in the quality of play expected from Gary Kasparov's average ELO performance rating based on slow play, recognition processes must be considerably more important than searching and evaluating. To the contrary, our data clearly show that grandmasters make appreciably more and bigger mistakes against other grandmasters when they have significantly less time than usual to select their moves. Our findings were based on objective computer analyses of errors in hundreds of actual serious games between grandmasters, rather than on (a) performance ratings that failed to take into account the variability of Kasparov's ELO rating, as dependent on statistical weaknesses of that system (see Chabris, 1999), or (b) subjective judgments of move quality [as in Calderwood et al. (1988), in which the judgments failed to distinguish between fast versus slow play in masters as well as (tellingly) the moves of strong versus much weaker players in slow play only].

According to the logic behind Gobet and Simon's study (among other research, see also Chase & Simon, 1973, for statements asserting that quick pattern recognition is likely to be the basic ability underlying chess skill), the definite and substantial decrement in the quality of grandmaster moves in rapid versus slower chess in our work would oppose their view that search and analysis of a move's consequences are not as important as rapid recognitional processes. As Holding (1985) stressed, the degree of opportunity to "think ahead" appears very important, too [see Lassiter's (2000) comments on Gobet and Simon's work, and Gobet and Simon's (2000) reply].

Perhaps the most reasonable way of reconciling these opposing theoretical positions is to conclude that, when more time is available, skilled players have both a greater opportunity to recognize more patterns as well as to analyze ahead. We currently do not possess an explicit model or theory that would make clearly testable predictions about when one process would be more important than the other and that would encompass the conflicting results described above.[1]

Much more counterintuitive was our finding that grandmasters play about equally well, even in rapid games, whether or not they have actual sight of the changing board positions. We could detect no significant differences between the number and magnitude of blunders made under blindfold or sighted conditions in the Monaco tournaments. Because most masters can play two or three blindfold games simultaneously without any special practice at this form of chess, such an ability [which invariably seems uncanny or amazing to outsiders, as Hearst and Wierzbicki (1979) and Hearst and Knott (2003) report] may offer special clues as to the bases of a master's skills. Chabris (1999) pointed out that one important objection to simple chunking theories of chess skill involves the production-system link between chunk recognition and move selection. How does recognizing relatively small chunks or patterns lead to the choice of specific moves, even if such theories can presumably handle performance effects involving recall of visually presented individual chess positions—the standard deGroot-Chase & Simon memory task? It seems clear that other, presumably higher-level processes must intervene between knowledge of patterns and selection of moves. These processes presumably involve associative factors and extensive search and evaluation. We suggest that visualization, perhaps along with some additional as yet unidentified higher-conceptual or representational techniques, may provide a neglected missing link.

Numerous verbal reports of very strong blindfold players [see Binet (1893, 1894) and Hearst and Knott (2003), which also include many masters' descriptions of how they think ahead and analyze in regular games] reveal that the changing positions of pieces on the board are rarely visualized in any very realistic or concrete way, like a photograph or interior mirror.

For example, reported representations typically do not contain pieces that actually resemble a horse or tower, or squares that are black or white. The representations are much more abstract, and are often described in terms of the functions of the pieces, like “lines of force”; a rook is a horizontal-vertical cross, a bishop an oblique power or trajectory. A surprised Binet drew the same conclusion a century ago, after initially expecting to find clear reports of photographic imagery in blindfold chess. More recent reports (Hearst & Knott, 2003) consistently show that the stronger the blindfold player, the more abstract (and even unverbalizable) the reported representations become. There is little or no evidence that masters can visualize the entire board all at once. They report “scanning” positions in successive fashion, taking in quadrants or sections of the board in each “imaginal glance” [see Kosslyn (1994) for similar conclusions about how complex images are generated, and Reingold et al. (2001)].

Chabris (1999) used the term “cartoon” to refer to these kinds of representations. Cartoons have the characteristics of distorting actual physical features, spatial relations or distances, of highlighting important information, and of obscuring unimportant information. Saariluoma and Kalakoski (1997, 1998) found that strong players, even without sight of any board or pieces, successfully followed games presented to them one move at a time in regular chess notation, either auditorily or visually, and that they tended to be guided mostly by important features and to neglect insignificant features of an unfolding game.

Numerous masters have commented on how blindfold chess resembles regular chess, where potential but not actual positions must be visualized and evaluated. We mentioned in the introduction to this report that it is not uncommon for masters to state that the sight of actual pieces in a regular game interferes with their analysis of alternative moves in the position. The psychologist-chessmaster Krogius (1976) enumerated and calculated the likelihood of some of the kinds of errors of commission or omission that players make in their forward analysis during sighted games, such as occasionally forgetting that a piece has been captured or is no longer on a given square, or that a piece now occupies a particular square which was not the case at the beginning of the analysis. And many blindfold champions of the past and present prefer not even to have an empty chessboard visible to them during blindfold games, as has been the case in the Monaco tourneys. For them it is just another source of interference with their visualization and analysis.

How many other areas of expertise involve processes like those in blindfold chess: “mental” reasoning in mathematics, physics, architecture, etc.? Practice in playing blindfolded at an early stage of learning regular chess is recommended by a good number of masters and grandmasters, especially those trained in Soviet Russia where many instructional techniques were developed and compared. Among other similar commentaries, Grandmaster Jonathan Tisdall (1997) states that his transition from strong but relatively unimpressive play as an international master (the step below grandmaster) into much stronger play leading to his achieving the grandmaster title was helped tremendously by his adoption of advice to play over “in his head” many recorded games from books and periodicals. Other grandmasters report that they regularly engage in such activities. Would “mental practice” (often recommended to develop motor skills in golf, baseball, or tennis) help, say, in mastering problems in arithmetic? There does not appear to be much solid data on this issue, although in the past such mental practice has been part of the curriculum in a good number of elementary schools around the world (see also Chabris, 1999, p. 21 for relevant references to physicists’ and architects’ thinking and sketches).

It is important to mention that even though the number and magnitude of errors in blindfold versus sighted games did not differ by our computer-based criteria for a blunder, the types of blunders may sometimes differ qualitatively. Hearst and Knott (2003) give several examples in which masters playing without sight of the board do occasionally forget, say, whether or not their or an opponent's piece has already moved from its previous square to another square, and as a result they may place a strong piece where it can be captured by a mere pawn. This tragedy would be very unlikely to occur in a regular game where you can actually see where the pawn is, though it could happen in the course of analyzing a variation several moves ahead in regular chess. Or blindfolded players sometimes think that a move which they considered as only a possibility has actually been played. We are currently trying to categorize blunders in blindfold versus sighted chess to see when and if such differences clearly occur and we have the strong expectation that they do. Some kinds of blunders may almost never occur in sighted chess but be found occasionally in blindfold chess. No computer can easily perform this type of analysis for us, and a team of masters judging crass blunders in, say, the Monaco tourneys seems necessary to accomplish this kind of analysis.

Another possibility is that grandmasters adapt a generally more cautious style in blindfold chess than in sighted chess and thus they avoid complex positions where big blunders may be most likely to occur. From studying hundreds of games of both types, Hearst and Knott (2003) have some reason to agree with this possibility.

Finally, several chessmasters have suggested to us that players may concentrate harder or are more highly motivated in blindfold than in sighted chess, or in slow chess than in rapid chess, and that this factor somehow accounts for the effects reported in this paper. However, this possibility seems unlikely since the prize money is excellent (called "mouthwatering" by the world's leading chess magazine, New In Chess) in the Monaco tourneys, and rapid games and blindfold games are combined equally to determine final standings and prizes.

Note

1. Regardless of psychological theorizing, it is interesting that in a remarkable joint letter sent to the International Chess Federation (FIDE) in April 2001 three present or past world champions (Anatoly Karpov, Gary Kasparov, and Vladimir Kramnik), who rarely are in unanimous agreement, expressed a series of complaints that had disturbed all of them. One of them pertained to FIDE's decision to cut the total time limit in serious tournament games by approximately a half. The three grandmasters stated that "drastically shortening the amount of time available during a game is an attack on both the players and the artistic and scientific elements of the game of chess itself." The goal may be admirable, to popularize the sport of chess, "but it is impossible to achieve it by assaulting the very things that elevate the game most of all: beautiful games of chess, traditional top tournaments, and the quest for the World Championship."

   Kramnik later said in an interview that he had "never spoken to a player who was in favor of the new time control" and that if FIDE were not reined in, chess games would eventually be reduced to "15 min."

Acknowledgments

We acknowledge the support of grants from the Harvard University McMaster Fund and the Harvard University Psychophysics Fund. Many of the numerical results and their possible interpretations were included as Experiment 4 in Christopher Chabris' doctoral dissertation (Chabris, 1999), especially with respect to the first goal of the research, which bore on the recognition versus search-and-evaluation issue. A summary of our preliminary results was presented by Chabris at the Schloessman Seminar on "The Expert in Modern Societies: Historical and Contemporary Perspectives", held in Berlin, Germany in November 1998. John R. Anderson, Neil Charness, Charles Crittenden, Stephen Kosslyn, Ken Nakayama, Pertti Saariluoma, Daniel Simons, and Sheldon White provided valuable comments on the work and this article. Dan Falcon contributed useful technical assistance.

References

Bachmann, T., & Oit, M. (1992). Stroop-like interference in chess players' imagery: An unexplored possibility to be revealed by the adapted moving-spot task. *Psychological Research*, *54*, 27–31.

Batchelder, W., & Bershad, N. (1979). The statistical analysis of a Thurstonian model for rating chess players. *Journal of Mathematical Psychology*, *19,* 39–60.

Binet, A. (1893). Les grandes memoires: Resume d'une enquete sur les joueurs d'echecs. *Revue des Deux Mondes*, *117*, 826–859. In M. L. Simmel & S. B. Barron (Trans.). (1966). Mnemonic virtuosity: A study of chess players, *Genetic Psychology Monographs*, *74*, 127–162.

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

Calderwood, B., Klein, G. A., & Crandall, B. W. (1988). Time pressure, skill, and move quality in chess. *American Journal of Psychology*, *101*, 481–493.

Chabris, C. F. (1999). *Cognitive and neuropsychological mechanisms of expertise: Studies with chess masters*. Unpublished doctoral dissertation, Harvard University.

Charness, N. (1992). The impact of chess research on cognitive science. *Psychological Research*, *54*, 4–9.

Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In W. G. Chase (Ed.), *Visual information processing* (pp. 215–281). New York: Academic Press.

Church, R. M., & Church, K. W. (1983). Plans, goals, and search strategies for the selection of a move in chess. In P. W. Frey (Ed.), *Chess skill in man and machine* (2nd ed., pp. 131–156). New York: Springer.

de Groot, A. D. (1946). *Het denken van de schaker*. (The thought of the chess player.) Amsterdam: North-Holland.

de Groot, A. D. (1978). *Thought and choice in chess*. The Hague: Mouton.(Originally published 1965).

de Groot, A. D., & Gobet, F. (1996). *Perception and memory in chess: Studies in the heuristics of the professional eye*. Assen, The Netherlands: Van Gorcum.

Elo, A. E. (1986). *The rating of chessplayers, past and present* (2nd ed.). New York: Arco.

Ericsson, K. A., & Staszewski, J. J. (1989). Skilled memory and expertise: Mechanisms of exceptional performance. In D. Klahr & K. Kotovsky (Eds.), *Complex information processing: The impact of Herbert A. Simon* (pp. 235–267). Hillsdale, NJ: Erlbaum.

Glickman, M. E. (1995). Chess rating systems. *American Chess Journal, 3,* 59–102.

Gobet, F., & Simon, H. A. (1996). The roles of recognition processes and look-ahead search in time-constrained expert problem solving: Evidence from grand-master-level chess. *Psychological Science*, *7,* 52–55.

Gobet, F., & Simon, H. A. (2000). Reply to Lassiter. *Psychological Science*, *11,* 174.

Hartmann, D. (1989). Notions of evaluation functions tested against grandmaster games. In D. F. Beal (Ed.), *Advances in computer chess* 5 (pp. 91–141). Amsterdam: North-Holland.

Hearst, E., & Knott, J. (2003). *Playing chess blindfolded: A key to chess improvement, a controversial history, and a psychologist's domain of study*. (Book in preparation).
Hearst, E., & Wierzbicki, M. (1979). Battle royal: Psychology and the chessplayer. In J. H. Goldstein (Ed.), *Sports, games, and play: Social and psychological viewpoints* (pp. 29–63). Hillsdale, NJ: Erlbaum.
Holding, D. H. (1985). *The psychology of chess skill*. Hillsdale, NJ: Erlbaum.
Kosslyn, S. M. (1994). *Image and brain: The resolution of the imagery debate*. Cambridge, MA: MIT Press.
Krogius, N. (1976). *Psychology in chess*. Great Neck, NY: RHM Press.
Lassiter, G. D. (2000). The relative contributions of recognition and search-evaluation processes to high-level chess performance: Comment on Gobet and Simon. *Psychological Science*, *11*, 172–173.
Milojkovic, J. D. (1982). Chess imagery in novice and master. *Journal of Mental Imagery*, *6*, 125–144.
Reingold, E. M., Charness, N., Pomplun, M., & Stampe, D. M. (2001). Visual span in expert chess players: Evidence from eye movements. *Psychological Science*, *12*, 48–55.
Saariluoma, P. (1991). Aspects of skilled imagery in blindfold chess. *Acta Psychologica*, *77*, 65–89.
Saariluoma, P. (1995). *Chess players' thinking: A cognitive psychological approach*. London: Routledge.
Saariluoma, P., & Kalakoski, V. (1997). Skilled imagery and long-term working memory. *American Journal of Psychology*, *110*, 177–201.
Saariluoma, P., & Kalakoski, V. (1998). Apperception and imagery in blindfold chess. *Memory*, *6*, 67–90.
Simon, H. A., & Chase, W. G. (1973). Skill in chess. *American Scientist*, *61*, 394–403.
Tisdall, J. (1997). *Improve your chess now*. London: Cadogan.