

## **Forward search, pattern recognition and visualization in expert chess:**

### **A reply to Chabris and Hearst (2003)**

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**After September 30<sup>th</sup>, 2003:**

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### **Abstract**

Chabris and Hearst (2003) produce new data on the question of the respective role of pattern recognition and forward search in expert behaviour. They argue that their data show that search is more important than claimed by Chase and Simon (1973). They also note that the role of mental imagery has been neglected in expertise research and propose that theories of expertise should integrate pattern recognition, search, and mental imagery. In this commentary, I show that their results are not clear-cut and can also be taken as supporting the predominant role of pattern recognition. Previous theories such as the chunking theory (Chase & Simon, 1973) and the template theory (Gobet & Simon, 1996a), as well as a computer model (SEARCH; Gobet, 1997) have already integrated mechanisms of pattern recognition, forward search and mental imagery. Methods for addressing the respective roles of pattern recognition and search are proposed.

### **Keywords**

Decision making, expertise, imagery, pattern recognition, problem solving, search

## Introduction

The respective roles of pattern recognition and search in expert problem solving have been an important topic of research in cognitive science. Key results were provided by De Groot (1946; 1978), who showed that world-class chessplayers did not consider many more moves in their search than weaker (but still expert) players, but that they zoom in onto potentially good moves much earlier. As De Groot put it, after five seconds, world-champion Max Euwe was further in his understanding of a position than a strong amateur after fifteen minutes. De Groot concluded that perception, giving rapid access to knowledge and honed by years of practice and study, was a key determinant of chess skill, a conclusion supported by the fact that skilled players are able to memorize briefly-presented positions almost perfectly.

De Groot's ideas were further developed in Chase and Simon's (1973) chunking theory, which proposed that pattern recognition explains both how experts show a remarkable memory for domain-specific material and how search can be carried out smoothly in the mind's eye, where future positions are imagined. A contrasting view was taken by Holding (1985; 1992), who denied the importance of pattern recognition; instead, based on the way computers play chess, he proposed that chess skill is underpinned by search, general knowledge and evaluation. As a test for the respective importance of recognitional and calculational abilities, Calderwood et al. (1988) compared the quality of play in speed and in normal chess, and Gobet and Simon (1996a) reported data about Kasparov's matches against national teams, where he played simultaneously against from four to eight players. In both cases, the loss in play quality

was considered small, thus supporting the hypothesis that pattern recognition plays a predominant role.

Chabris and Hearst (2003) criticize these two studies, the first because the quality of moves was evaluated subjectively by two grandmasters (a measure that failed to distinguish class B and masters in normal play), the second because Gobet and Simon reported no information about variability in Kasparov's play during these matches.<sup>1</sup> They provide data from six editions of the Monaco tournament, where top-level grandmasters played both *rapid* games (less than 30 seconds per move, on average) and *blindfold* games. In these blindfold games, played at about the same speed, players could not see the actual position. Chabris and Hearst compare these results with *classical* games (about 3 minutes per move, on average) between the same players. In the three conditions, a strong computer program was used to identify blunders (in general, defined as actual moves evaluated 1.5 pawn below the program's best choice).

Chabris and Hearst found that players committed more blunders per 1,000 moves in rapid games (6.85) and blindfold games (7.63) than in classical games (5.02). The frequency of blunders was statistically significantly smaller in classical games than in rapid and blindfold games. However, the frequencies were not reliably different in rapid and blindfold games. The same pattern of results occurred with more stringent criteria for

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<sup>1</sup> This is corrected here. Including the results of four more matches reported in Gobet and Simon (2000b), the median performance of Kasparov's results was 2682 Elo, with an interquartile range 203.5.

errors (difference larger than 3, 6, or 9 pawns instead of 1.5 pawn), and when the magnitude of errors was compared.

Chabris and Hearst interpret these data as opposing Chase and Simon's (1973) and Gobet and Simon's (1996a) view that pattern recognition is more important than search in expert chess. They also criticize the assumption that move selection is based upon chunk recognition, as relatively small chunks are unlikely to help the choice of specific moves. Instead, they propose that higher-level processes (including associative factors, extensive search and evaluation) intervene between chunks and selection of moves. They suggest that "visualization, perhaps along with some additional as yet unidentified higher-conceptual or representational techniques, may provide a neglected missing link" (p. 644). They finally mention several implications of chess masters' ability to play blindfold chess at high level and question the value of eye-movement studies of chess skill. They conclude that both swift pattern recognition and analyzing ahead seem important for chess skill and that the controversy over the dominance of either mechanism "appears currently unresolvable and perhaps fruitless" (p. 637).

### **Previous theories of search and pattern recognition**

Chabris and Hearst's conclusion about the necessity of combining the role of pattern recognition and search is not disputed. Indeed, it is what de Groot (1946),<sup>2</sup> Chase

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<sup>2</sup> While De Groot later disagreed with the details of Chase and Simon's (1973) chunking theory, in particular about their emphasis on pattern recognition (e.g., chapter 9 of De Groot & Gobet, 1996), his 1946 book clearly acknowledged both the role of perception in chess skill and the importance of look ahead (e.g., De Groot, 1946/1978, p.

and Simon (1973), Calderwood et al. (1988), Saariluoma (1990), Charness (1991), Gobet and Simon (1996a; 1998) and others have been proposing all along, and it is what has been more recently formalized in a computational model (Gobet, 1997). Probably due to the space constraints of the “short communication” medium, Chabris and Hearst kept their review of the literature to a minimum. This was unfortunate, as most of the theoretical conclusions they draw are either unfounded or duplicate previous work.

To begin with, they suggest that visualization may provide “a neglected missing link” (p. 644) between pattern recognition and move selection, and that mental imagery has been neglected in expertise research. But this ignores the fact that mental imagery plays an essential role in Chase and Simon’s influential chunking theory (hence the title “The mind’s eye in chess” in one of their papers), and that it was indeed a recurring theme in Simon’s studies of problem solving (Simon, 1972) and expertise, for example in physics (Larkin, Mc Dermott, Simon, & Simon, 1980) and in the role of diagrams in economics (Tabachnek-Schijf, Leonardo, & Simon, 1997).

Chabris and Hearst (pp. 643-644) repeat a number of criticisms made earlier against the chunking theory by Holding (1985, 1992). They contrast search mechanisms and *initial* pattern recognition of candidate moves, while Chase and Simon (1973; see also Gobet & Simon, 1998, 2000b, and Gobet, 1997) were very clear that pattern recognition

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320). After all, De Groot devoted most of the 460 pages of his book to a detailed analysis of how the search for a good move is carried out by chess players!

occurs recursively during search. Two other criticisms—the relatively small size of the chunks, and the necessity for higher-conceptual knowledge structures—were successfully addressed in the template theory (Gobet & Simon, 1996b, 2000a), which adds to the chunking theory the hypothesis that common chunks evolve into more complex structures having schema-like properties.

Application of the template theory to the question of search led to a formal model, called SEARCH, which explicitly combines pattern recognition, search, and mental imagery (Gobet, 1997). SEARCH also includes assumptions about the time needed for cognitive operations, as well as assumptions about the “fuzziness” of the images kept in the mind’s eye. Chunks and templates favour deeper search, because they suggest potential moves automatically (templates also facilitate long-term memory encoding, maintenance of information in the mind’s eye, and more abstract search). On the other hand, they favour shorter search, as they provide powerful evaluations which cut down the need for search. The net product, as shown in computer simulations, is that average depth of search follows a power function of skill—a prediction consistent with the data. Given that SEARCH integrates the three components of chess skill identified by Chabris and Hearst, it is unfortunate that these authors did not refer to it in their discussion. In particular, an obvious prediction of the model is that “when more time is available, skilled players have both a greater opportunity to recognize more patterns as well as to analyze ahead” (Chabris & Hearst, p. 644).

### The Monaco data and their analysis

As with Gobet and Simon's analysis of Kasparov's data, the use of the naturalistic data provided by the Monaco tournaments raises new methodological problems, and it is important to mention some of these here, so that they can be overcome in future research. With current technology, the use of a computer program to assess the quality of moves is a mixed blessing. Granted, one gains in objectivity; however one has to content oneself with a rather blunt way of measuring errors—essentially only picking up gross tactical mistakes. A good case can be made that, particularly at the top level, games are lost more by the accumulation of small errors than by blunders (Jansen, 1992; Simon, 1974). As suggested by Chabris and Hearst, a more powerful—but also more complex and subjective—approach is to combine computer analysis with grandmasters' opinion.

Most importantly, there are problems with the interpretation of the data.<sup>3</sup> As chunking-based theories predict that, rather unsurprisingly, a decrease in thinking time

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<sup>3</sup> There are also problems with Chabris and Hearst's data analysis: the use of the chi square statistic is inappropriate with their frequency data, as it violates the assumption of independence of the test (e.g., Lewis & Burke, 1949), at two levels of aggregation. Moves in a game depend upon the previous moves (e.g., the presence of a blunder may increase the likelihood of another blunder, Krogus, 1976) and games are contingent upon previous games (e.g., a lost game may affect a player's motivation and thus the likelihood of a blunder in the next game). A related problem is that a few players may have accounted for most of the blunders.



will lead to a decrement in the quality of play (e.g., Gobet & Simon, 1996a), the critical question is the extent of this decrement. Chabris and Hearst (p. 644) claim the decrement between classical and rapid games was “definite and substantial,” but this is disputable. With a more than sixfold decrease in thinking time between classical and rapid games, is a 36.5% increase in the number of blunders (from 5.02 to 6.85 per 1,000 moves) substantial? Or, using as reference class not the number of blunders, but the total number of moves played, a 0.183% increase? And, with respect to the magnitude of blunders,<sup>4</sup> an increase of 0.49 pawn units? Without either quantitative theoretical predictions or information about the rate of blunders made by weaker players, it is simply impossible to tell. In any case, it could be equally reasonably argued that these results provide direct support for pattern-based recognition theories. If search was key, and assuming that the number of nodes visited during look-ahead search is proportional to thinking time, cutting this time by six would seem to produce a larger increment in the number of blunders than 36.5% (with number of blunders as reference class) or 0.183% (with number of moves as reference class), as observed. By contrast, pattern-recognition models, which emphasize highly selective search, are less sensitive to reduction in the number of nodes searched.

### **Roles of pattern recognition and search: A fruitless controversy?**

Given that both are often intertwined, is it fruitful to talk about the dominance of pattern recognition over search? At least four reasons suggest that this is the case. First,

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<sup>4</sup> Obviously, a blunder of 0.49 (half a pawn unit) is likely to make a difference in a master game. But, here, we are talking about the difference between *blunder magnitudes*.

research in computer science shows that knowledge and search can be varied independently. For example, Berliner (1981) provides estimates of how much search may be replaced by tactical, positional and strategic knowledge. Assuming that pattern recognition explains how knowledge is accessed efficiently in humans, these results could be used to design experiments with human players where the consequences of providing additional knowledge are studied. Second, there is clear experimental evidence that strong players can sometimes choose the optimal move with minimal search (in less than 10 seconds) (e.g., Charness, 1981). Further experiments could help specify the conditions that allow such rapid and selective search.

Third, verbal protocols and the measures developed by De Groot (1946) provide a powerful means of disentangling the contribution of pattern recognition and search; in particular, theories emphasizing the predominance of either mechanism make differential predictions about how measures such as the number of moves searched and the degree of selectivity vary as a function of skill (Gobet, 1998). Finally, computational modelling may help generate testable predictions about the complex interplay between perception and search. For example, SEARCH (Gobet, 1997) makes quantitative predictions about how moves are generated during lookahead search, depending upon the skill level: with a network containing 150,000 chunks, approximating grandmaster level, 15% of the moves are generated by heuristics, 23% by chunks, and 62% by templates.

### **Blindfold chess**

My comments on blindfold chess will be short, as the Monaco data, while surprising, are open to the criticism (Chabris & Hearst, p. 646) that players may have used a more prudent style in this condition, which makes comparison with classical and rapid games difficult. Moreover, Chabris and Hearst's discussion of blindfold chess relies heavily on anecdotal evidence, some of which is disputable. For example, they defer to experts' opinion to the effect that playing blindfold chess improves one's skill, but one could equally point to other experts claiming that playing blindfold is useless, if not dangerous (e.g., Dextreit & Engle, 1981; Saariluoma, 1995). One could also argue that the direction of causality goes in the opposite direction: the ability to play blindfold chess is a consequence of chess skill, made possible by the presence of a large knowledge base of chunks and templates, and improving one's ability to play blindfold chess may not benefit skill in standard chess (Gobet & Jansen, in press). This view gains credence inasmuch as the template theory explains the experimental results on blindfold chess reasonably well (Campitelli & Gobet, in press), and makes testable predictions: similar eye movements should be observed in blindfold chess as in normal chess.

### **Conclusion**

Even with substantial implicit knowledge held in their evaluation function, computers need search spaces orders of magnitude larger than humans' to match their level. But while computers can compensate the lack of knowledge by intensive search, humans cannot, both because of the prohibitive size of the search space and their information-processing limits. Instead, they have to rely upon selective search, made

possible by pattern recognition. Chabris and Hearst provide valuable data, whose message is similar to Gobet and Simon's (1996): reduction in thinking time leads to loss in the quality of play. The disagreement lies in the magnitude of this loss, and its consequences for theories of expertise. This article has argued that current theories, which integrate pattern recognition, search and mental imagery, provide clear-cut mechanisms that can be used to make quantitative predictions about the respective importance of pattern recognition and search. Far from fruitless, the pattern-recognition vs. search controversy promises exciting research ahead.

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