[To appear in T. Redman (in press), Education and chess]

Training in chess: A scientific approach

Fernand Gobet

University of Nottingham

Peter J. Jansen

Carnegie Mellon University

Address correspondence to:

Dr. Fernand Gobet

ESRC Centre for Research in Development, Instruction and Training

School of Psychology

University of Nottingham

Nottingham NG7 2RD

United Kingdom

email: frg@psyc.nott.ac.uk

+ 44 (115) 951 5402 (phone)

+ 44 (115) 951 5324 (fax)

Training in chess: A scientific approach

Fernand Gobet & Peter J. Jansen

Research in psychology has made important progress towards unraveling the secrets of chess players' minds. It is the goal of this chapter to show how recent findinds in cognitive psychology can be applied to improve techniques of chess training, teaching, and learning. We start by giving an overview of the state of research on chess players' memory, perception and problem solving. In Section 2, we review a recent psychological theory that synthesizes previous work. Building on this theory, we then review various training techniques and discuss their pros and cons. We conclude with some general considerations on chess teaching and learning.

In this chapter, we have in mind a player who has already mastered the basics of chess (with a level of, say, 1800 Elo) and would like to reach a higher level of expertise (say, 2400 Elo). Hence, we will not say much about teaching chess to beginners or about training at grandmaster level, although it is to some extent possible to generalize from our considerations. We also expect our player to be a strongly-motivated *competitive* player. While many players are legitimately interested in learning about chess history or in enjoying combinations and well-played games, we are talking here about a player who wants to progress in order to perform at a competitive level. (Our recommendations would likely be different if excellence in chess were measured, not by norms and Elo rating, but by an "academic" examination!)

It is almost a tradition in the literature of chess training that authors claim to be the first to devote a book to this topic. However, as the bibliography at the end of the chapter shows, they normally stand on the shoulders of a remarkable series of masters and grandmasters. Although we do acknowledge our intellectual debt in this regard, and very few of the techniques we discuss are original, we believe this is the first time that chess training techniques have been systematically organized and criticized from the point of view of a scientifically motivated theory.

1. Chess psychology: An overview

Since the end of the nineteenth century (Binet, 1894), chess has been a popular topic of research in *cognitive psychology*, the field of scientific psychology that studies perception, memory, learning, and thinking. Classical landmarks include Adriaan De Groot's doctoral dissertation (De Groot, 1946), translated into English as De Groot (1978), Newell and Simon's (1972) research on problem solving, and Simon and

Chase's (1973) work on chess memory and perception.[1] For a detailed description of recent work on chess psychology, we refer to the technical literature (e.g., De Groot & Gobet, 1996; Gobet, 1993; Gobet, de Voogt, & Retschitzki, in press; Holding, 1985; Saariluoma, 1995).

It is not feasible to discuss the whole history of chess psychology in detail in the context of this chapter, but the key findings on chess expertise can be summarized in the following statements:

1. Chess players have a highly efficient mode of (high-level) perception. They can access the key elements of a position rapidly.
2. Chess players show a remarkable memory for chess positions and games. This ability typically does not extend beyond chess.
3. Chess knowledge is encoded at several levels, in particular at a low, *perceptual level*, where patterns of pieces are stored, and at a high, *conceptual level*, where information about plans, evaluation, etc., is stored. These various types of encoding, with rich indexing and a high level of cross-referencing, account for chess players' excellent professional memory.
4. Chess players search highly selectively. It is rare that they analyze more than one hundred positions in the search tree before choosing a move.
5. There is no difference between the search algorithm of class A players (Elo 1800-2000) and that of Grandmasters.
6. Masters lose relatively little of their skill when they play simultaneous games or speed chess.

2. The template theory

The components of chess expertise have recently been synthesized in the "template theory" (Gobet & Simon, 1996), which is a refinement of theories developed by De Groot, Chase, Newell and Simon. Some aspects of this theory have been implemented in a computer program that simulates chess players' behavior in various memory and perception experiments. Computer programs are an important tool for developing theories in cognitive psychology. They allow a much more rigorous specification than

[1]Chess psychology has attracted intellectual giants indeed: Allen Newell and Herbert Simon are recognized as the fathers of modern cognitive psychology and of artificial intelligence. Simon was awarded the Nobel prize in economics in 1979.

verbal theorizing: the programs' operations can be compared to human behavior, and discrepancies indicate that the theory is either incomplete or incorrect.

The template theory states that the human cognitive system comprises three main modules: a *visuo-spatial imagery system*, a *short-term memory* (STM), where information is briefly stored, and a *long-term memory* (LTM), which consists both of structures indexing the information and the information itself. (Note that players can be said to use, in addition, an *external memory*: the board itself with the pieces.) Long-term memory consists of *declarative knowledge* (the 'what'), encoded as *schemata,* and of *procedural knowledge* (the 'how'), encoded as *productions*. Perceptual and conceptual information that can be used as units are called *chunks*, and constitute the building blocks out of which knowledge is constructed. Schemata can be visualized as nodes connected by links, where the nodes refer to concepts, and links to relations between these concepts. For example, in "Pd4 defends Pe5", the two concepts Pd4 and Pe5 are connected by the relation "defense."

Figure 1 illustrates a more complex example—a subpart of the knowledge related to a typical isolated Queen's Pawn:

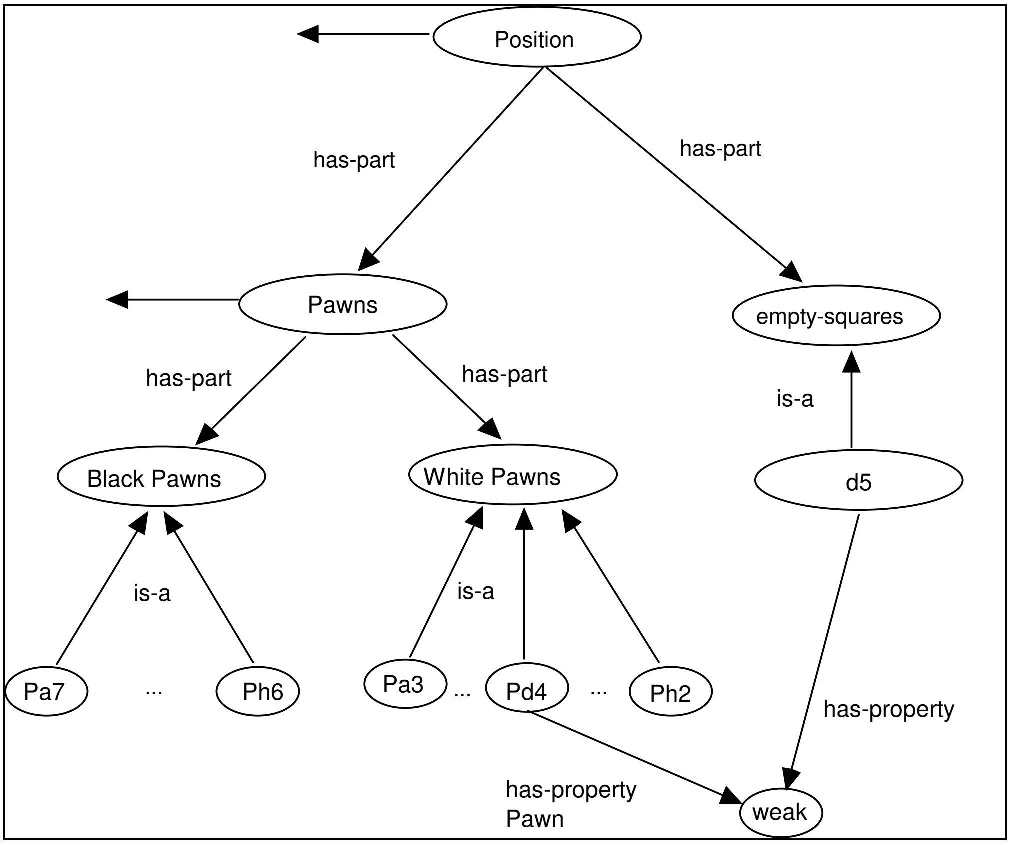

Figure 1: Example of a schema

Productions are knowledge units made up from a set of conditions and actions. For example, "IF there is an open file X, AND you have a Rook, THEN place the Rook on X," or "IF you have a passed Pawn X, THEN push X." In the last example, the condition tests the presence of a passed Pawn, and the action recommends pushing it.

Productions allow information to be processed rapidly and unconsciously, and may be the mechanism underlying what players call *intuition*. For example, in the position shown in Figure 2, most masters will almost immediately consider 1. Bxh7+ as a plausible move. The critical pattern is perhaps the presence of a Bishop on d3, of Black's king-side castle, of a Pawn on e5, and the absence of a defensive Bishop on e7. Strong players will even "intuitively" anticipate that the Black king will be mated if it is goes back to g8 after 1.Bxh7+ Kxh7 2.Ng5+, effortlessly proposing the sequence 3.Qh5 Re8 4.Qxf7+ Kh8 5.Qh5+ Kg8 6.Qh7+ Kf8 7.Qh8+ Ke7 8.Qxg7+. Thus, productions make it possible for strong players to search deeper.

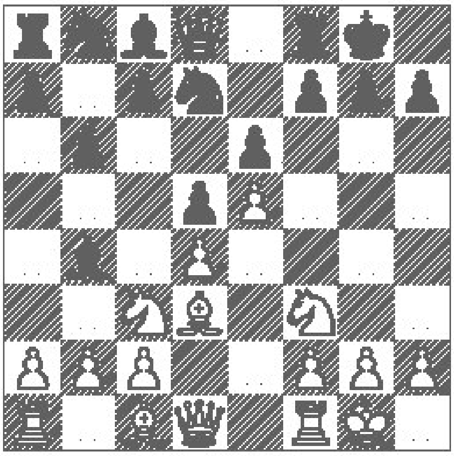

Figure 2: Example of a position eliciting an automatic, intuitive solution.

Access to information is rapid once it has been learned, but learning is slow. It has been estimated that it takes about ten seconds to learn a new chunk in LTM (Simon & Chase, 1973). Through recognition processes, patterns of pieces on the external board or in the visuo-spatial store activate LTM chunks. When the position is relatively well-known to the player, special chunks—called *templates*—are activated. Templates are simply large chunks that possess *slots* to encode information rapidly. Both chunks and templates point to information related to the configuration of pieces currently focused on. This information may include possible moves, the relative strength or weakness of squares, the opening the position may have come from, links to other templates, and so on.

Search for a good move is greatly facilitated when a template has been accessed, because useful information that cuts the amount of search down is accessible directly. This information may be available in an *explicit* form (i.e., it may be accessed consciously and communicated to other people) or in an *implicit* form (i.e., the player is unaware of what information is used, and how it is used). Search implies an interplay between information on the external board, the visuo-spatial store, information in STM, and information in LTM. Due to the limits in capacity and access time of STM, and to the risks of decay and interference in the visuo-spatial store, search is a difficult process, and prone to errors. The advantage of accessing chunks is that groups of pieces may be stored and manipulated as units. Templates offer the additional possibility of updating portions of the board rapidly, since they incorporate slots into which values of variables may be encoded easily. Accessing chunks and templates thus make search easier.

In summary, becoming a skilled player requires the acquisition of a variety of well-indexed and cross-referenced kinds of knowledge—chunks, templates, and procedures. We may infer a few general educational principles from the theory we have sketched:

1. Learning occurs best *from the simple to the complex*. This principle may also be described as gradually building up from the known to the unknown. It follows from the theory, because the building blocks of knowledge must be acquired first, before they can, for example, be used as variables in templates.
2. Learning occurs best when the *elements to be learnt are clearly identified*. This helps provide a context for indexing as well as guidance for generalization.
3. Learning occurs best by following an *"improving spiral,"* where the learner comes back to the same position, or material, and adds increasingly more complex new information to its knowledge-base. This process increases the chance of creating cross-referencing links.

Principles 1 and 2 have also been proposed by other leading experts in education (Anderson, 1990; Anderson, Corbett, Koedinger & Pelletier, 1995; Gagné, Briggs & Wagner, 1989; Travers, 1978). However, this view has not been unchallenged. There is currently a heated debate whether, instead of learning the material in a progressive way, learners should be immersed right away in complex problems, possibly with some help from the teacher (the so-called "situated-learning approach" and "problem-based approach," respectively). We will stick to the "traditional approach," which has received the strongest empirical support.

We now employ the conceptual framework offered by the template theory to review various chess training techniques. In general, it is hard and even useless to train the STM and imagery components as such, and it is more useful to develop the knowledge base, because the former relate to hardware variables of the human body, probably unchangeable even with current progress in neurophysiology, while the acquisition of the latter is known to be relatively easy. As mentioned earlier, we believe that depth of search or intuition are side effects of a well constructed knowledge base.

3. Acquiring chess knowledge

What is the best way to acquire what De Groot (1978) calls the "system of playing methods" that a master has at his disposal and that is presumably necessary for reaching mastership in chess? We may organize chess knowledge along three dimensions (see Table 1) which will be used to present the material of this section.

A. Type of encoding

1. Explicit
2. Implicit

B. Diachronic dimension

1. The opening
2. The middle game
3. The endgame

C. Chess contents

1. Tactics
2. Strategy

Table 1: The three dimensions along which knowledge acquisition is discussed in this chapter.

3.1. Type of knowledge

We have proposed that (chess) knowledge is encoded with one of two types of data structures: *declarative*, which states relations between concepts, and *procedural*, which encodes action(s) to carry out given a set of conditions. Typically, a subset of both types of knowledge is consciously accessible (*"explicit" knowledge*), although most is not (*"implicit" knowledge*). One could say that explicit knowledge is implicit knowledge to which special retrieval information—typically verbal information—has been attached. We now treat these two aspects of chess knowledge in turn.

3.1.1. Explicit knowledge

It is clear that a huge amount of knowledge is explicit. The best examples are perhaps offered by the theory of openings,[2] by the theory of endgames, and by various types of methods to apply in particular types of positions. For example, given a Queen's Gambit Defense, exchange variation, a Master can clearly state that a worthwhile plan for White is to carry out a minority attack, with Rooks placed on b1 and c1, and that a position like the one shown in diagram 3 is advantageous for White. Rote knowledge of games or of sections of games is another type of explicit knowledge. What does the template theory have to say about learning such material? Mainly two (sad) things: learning is time consuming and forgetting will inevitably occur.

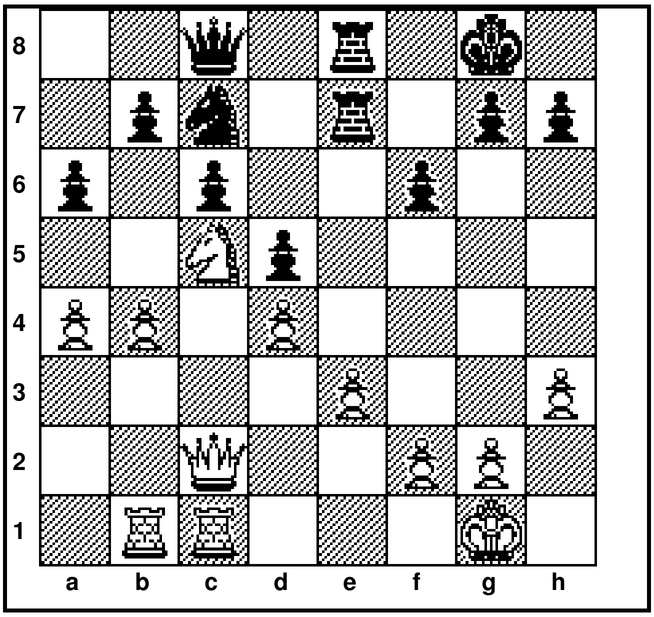

Figure 3: A typical position from the Queen's Gambit Accepted, Exchange variation. Masters know that in this type of position, Rooks are best placed on b1 and c1 (position after White's 29th move in the game Flohr - Euwe, Amsterdam, 1932).

[2]The term "theory" is used in a peculiar way in the chess literature. It refers to a compilation and analysis of variations and positions, and not, as is the case in most sciences, as a set of principles and laws summarizing a collection of observations.

Several practical recommendations may be inferred from the theory. First, one should *focus on a limited number of types of positions and openings*, and learn the various methods in these positions thoroughly. This focus is necessary due to the limited study time available and to the wealth of information to learn. As discussed below, this focus also facilitates access to the information through pattern recognition. Second, *repetition* will be necessary, both when learning opening lines and strategic ideas. It is a good idea to go over the same material several times, if possible using varying points of view. For example, when studying a game, one could first focus on the strategic aspects, then on the tactical aspects, and so on. Or when studying an opening line, one could first try to memorize and understand it using an opening textbook, then study games using this opening, then carry out one's own analysis.[3] This approach will offer a richly-indexed encoding of information, which helps prevent forgetting and allows easier access to memory traces.

Third, one should avoid spending too much time on *historical and anecdotal details*. Although such information may be useful in indexing knowledge, it has several disadvantages. It can become an overwhelming mass of information, dangerously attractive but not useful for competition. In addition, this information is usually not acquired and stored in an efficient way for competition. Finally, because of its intrinsic attraction, it may divert a player's attention from other, more relevant aspects. For example, knowing the opening and result of Lasker's 5th round game in the New York 1924 tournament, what White's winning percentage is with the Sveshnikov Sicilian, how to mate with two knights against a pawn, or remembering 1234 endgame studies can be fun, but take time and do not contribute to a player's competitive strength.

Fourth, one word about studying classics. This clearly has advantages, as is often stressed in the literature. For example, ideas are easier to understand in these games than in contemporary games, because the quality of defense was lower and games were more centered around a single theme than is the case nowadays. Classical games were also less obscured by many subtleties in the opening. However, there is the danger that, in addition to overloading LTM with anecdotal material, studying classics leads to the creation of schemata that will not be useful in practice, because the type of positions

---

[3] Carrying out one's own analysis should not be done at the beginning, because it inefficient–not all key concepts are available–and will most likely only duplicate established analysis.

met in these games is unlikely to be seen again. This disadvantage is not fatal, however, and may be avoided by studying a judicious mixture of classical and modern games.

3.1.2. Implicit knowledge

While it is easy to describe the type of explicit knowledge that a strong player should possess, it is harder to describe what type of implicit knowledge should be acquired. According to the template theory, there are three different types of knowledge, which are all accessed through recognition processes: chunks and templates, schemata, and productions. Testing for the presence of implicit information is not easy, because players are themselves unaware of the details of its encoding.

As with explicit knowledge, the template theory suggests that it is better to learn a few opening variations in detail —though sufficiently broadly to cover all possible openings by the opponent—than to cover too many opening variations. Studying fewer openings enhances the likelihood that chunks and templates learned during training will occur in tournament games. As discussed below, recognizing plausible moves early on cuts down the search space. In addition, efficient productions will be encoded with specific conditions (productions with non-specific conditions are slow to apply because time is needed to instantiate them), and these conditions are likely to be related to features of the opening.

The question now arises: How to optimize learning so that key aspects of the position are recognized rapidly, and so that methods are applied efficiently? We believe that the best way to achieve this is by using computer technology to display positions and games, or, even better, to teach concepts: obviously, this technology cuts down the time spent in searching games and variants, and in moving pieces on the board, but it also permits one to analyze variations and sub-variations easily, which would only be visualized in the mind's eye in traditional teaching. Disadvantages of visualization in the mind's eye are that it is slower and more prone to errors than direct perception from external displays, and therefore it offers a less efficient encoding in LTM. We will come back to the question of computer instruction at the end of this chapter.

3.2. Diachronic dimension

3.2.1. The opening

Chess players' natural pragmatism has led most of them to appreciate the importance of studying openings. It is unclear, however, if they do it in an efficient way. For the opening phase, we give the following recommendations, which are quite consistent with our discussion of explicit and implicit knowledge.

First, one should be *selective*, and focus on a small repertoire of openings, which may be expanded later. Most books devoted to training agree on this point (for example, see Bönsch, 1987; Kotov, 1971). This selectivity is of course made necessary to some degree by the wealth of information offered by chess theory. But within a restricted repertoire, the required repetition and the predictive value of generalizations is likely to lead to rules more usefully applicable to later games than the less specific and less predictive knowledge derived from multi-opening systems.[4]

Second, one should find a *balance between rote learning and understanding*. On the one hand, there is no doubt that a huge amount of rote learning has to take place—chess is a domain too chaotic for everything to be derived from general principles, and also complex enough that theoretical variations cannot be calculated in real time without the risk of making serious errors, errors that have been eradicated during the slow evolutionary process of opening practice. On the other hand, new positions will be met, where rote knowledge cannot be applied. Therefore some general principles and rules of thumb had better be learnt, as well as the key ideas and themes in a given opening.

Third, openings should be *studied from different points of view*. For example, one should strive to link the knowledge of openings to typical middle-game positions and endgame positions, or, even better, to entire games. Doing so will speed up the creation of templates, which in turn will facilitate search and position evaluation. In addition, as seen before, this cross-referencing strengthens the memory traces of the material to learn.

Fourth, one should keep information about openings in a *central filing system*. Earlier, this role was played by the opening notebooks or card-indices that were maintained by several GMs and IMs. Nowadays, this data maintenance task is vastly facilitated by computer databases. Such repositories are important for several reasons. They allow reviewing the variations over time (memory is fallible!). They also facilitate the update of one's repertoire with new games and innovations. And of course, it is also easier to carry a laptop or a notebook than a library of dozens of volumes!

Finally, we should mention a useful technique, which we may call the *"decomposition method."* It consists in studying and playing basic endgames that may

---

[4] Some players specialize in gambit openings, and sometimes do quite well even against nominally stronger players—an illustration of the power of specialization! There is however the danger that this approach leads to a rather limited game, which may hamper progression. We suggest that one cycle of the spiral should take the player into less tactical positions.

occur from an opening position, by removing all pieces but kings and pawns from the position, and then gradually adding pieces of various sorts or varying aspects of the pawn structure (see Figure 4). This allows one to develop proficiency in endgames that may occur from one's opening repertoire. Note that keeping the pawns makes more sense than keeping other aspects in the position, as the pawn structure is less likely to change, and the position, or a similar one is hence more likely to actually occur in a game with the opening line under study.

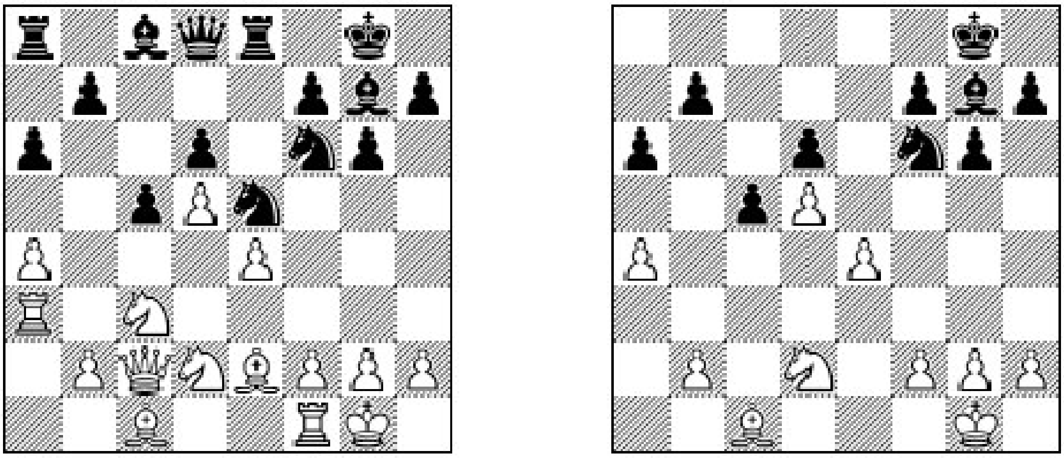

Figure 4: Example of the decomposition method, taken from the Benoni Defense. Would you rather play White or Black in this endgame?

3.2.2. The middlegame

Since most of what we have to say about the middlegame will be dealt with in the section on "chess contents," a few comments will suffice here. In the middlegame, perhaps more than in the study of openings, we can see the tension between learning specific facts and learning general principles. While our advice of specialization applies in this case as well, it would be quite unrealistic to expect all middlegame positions to fit known schemata. In particular, as there are a much larger number of positions, rote learning will be much less useful here than for opening positions.

Rather than by opening, the chess literature generally groups sets of positions around salient features of the position or the strategy employed. Books are available (e.g., Pachman, 1972) that treat certain middlegame themes in turn (such as the minority attack we mentioned before, or certain types of king side attacks, or various types of isolated queen-pawn positions, etc). Similarly, current database software allows relatively easy retrieval of games with such features. During training, the student may thus use these tools as a way to learn about the strategic and tactical features of the position likely to be met. Again, to make an effective selection of plans, themes, and positions for study, it is best to use typical positions stemming from one's chosen opening repertoire as starting points. Each theme can be looked at from different angles, studied as it occurs in actual games, possible resulting endgame situations, etc. Rote learning of a theme as exemplified in an actual game may help with indexing for further information retrieval.

Some players keep a catalog of certain middlegame positions that were important to them. They may serve as a comparison for positions encountered/studied later with certain common characteristics (chunks, templates). Sometimes, it is useful to study positions around the appropriate action rather than the conditions. Certain middlegame books bring positions together in which, for example, certain typical sacrificial attacks are applicable (e.g., the aforementioned bishop sacrifice on h7 or f7, or a rook sacrifice on g7, etc.).

3.2.3. The endgame

Several authors (Capablanca, 1963; Chéron, 1942) have stressed the necessity of studying endgames from an early point, because this allows the student to go from simple to more complicated concepts. There is no doubt that endgames are important, and that a good knowledge of them may be capitalized on to yield extra points in competitive games. As with openings, the lore of endgames is huge, and it is important not to waste time on irrelevant details. We propose three lines of study.

First, it is perhaps here that the concept of an "improving spiral" can be best applied. The student should start by acquiring basic knowledge in all domains of endgames (Pawn, Rook, etc.). Special emphasis should be given to Pawn and Rook endgames, as they are more likely to occur. It is important to pay attention to *typical positions*, and avoid all arcane knowledge, however exciting it may be. In further cycles, attention should be directed to slightly more complex endgames, with a constant check that knowledge acquired in previous cycles is still there. Only in later cycles of the spiral can you start spending time on more exotic endgames. We recommend books like Awerbach (1981a; 1981b) or Pachman (1977) which contain the necessary theoretical knowledge with enough practical slant. Coaches come in particularly handy with the study of endgames, as they can present material in the optimal order of difficulty.

Second, one should study well-commented endgames played by strong players (e.g., Euwe, 1962; Mednis, 1979; Schereschewski, 1994). This gives a practical gloss that theoretical books are lacking.

Third, one should study typical endgames resulting from the openings belonging to one's repertoire. In this respect, the "method of decomposition," mentioned above, is an excellent way to familiarize oneself with potential endgames.

3.3. Chess content

Traditionally, chess literature categorizes knowledge into two broad classes: tactical and strategic. From the point of view of our theory, both types of knowledge require the acquisition of chunks (the key features of a position indicating a combination or a strategic theme), templates/schemata (with them, positions are easier to search, and they give access to knowledge useful for this class of positions), and productions (they speed up thinking).

3.3.1. Tactics

Again, most chess trainers and teachers agree that practice and repetition are essential (e.g., Bönsch, 1987; Kotov, 1971). Traditional "quiz" books are quite useful, although we expect computer technology to greatly improve this part of chess teaching (see below). It is probably best to start with positions ordered by themes, then to move to positions randomly ordered (as is fairly usual among the quiz books). Again, typical combinations and themes should be studied when studying an opening. Finally, playing a computer opponent is a good way to improve one's tactical skills, particularly for players who are prone to errors with shallow combinations.

There are quite a few misconceptions about how to improve tactical skills, and three of them recur in the literature often enough to warrant our comments at this point: (1) visit each variant only once when thinking ahead; (2) practice with blindfold chess; (3) practice with artistic chess problems. (We hope the reader will forgive us for anticipating themes we deal with in more detail later).

(1) Kotov (1971; 1983) proposed that players should strive at calculating a branch of the search tree only once. We believe that this advice is likely to lead to disaster in competition games. As a matter of fact, empirical evidence shows that even top-level players often re-investigate the same variation (De Groot, 1978). We have more confidence in the technique of progressively diminishing the thinking time in practice games, also proposed by Kotov.

(2) We believe that playing blindfold chess is at best useless, and at worst harmful to one's development. The ability of playing blindfold comes more as a side effect of having acquired a well organized and easily accessible knowledge base (Ericsson & Staszewski, 1989; Saariluoma, 1995). Practicing blindfold as such may be harmful when it interferes with other types of training.

(3) Finally, training with artistic chess problems, proposed among others by Chéron (1942), is probably useless for chess competition. Gruber and Strube (1989) have shown that there is little transfer between these two variants of chess. According to the theory espoused here, practicing with chess problems will develop chunks of knowledge that are unlikely to be of use in competition games, because the conditions of their application are not met in these games. We have a somewhat better opinion of training with endgame studies (e.g., Dvoretzky, 1991), as long as the positions are not too far removed from practical play. Studying endgame studies with few pieces is probably excellent practice and may help develop imaginative and original ideas, but should come only when the basics on practical endgames have been covered (cf. discussion on endgames).

3.3.2. Strategy

Perusal of various textbooks on strategy has convinced us that the number of elements typically taught is rather limited, typically along three axes. There is first an abstract axis, including the notions of time, space and material; there is then a concrete axis, which relates to the activity of pieces and includes notions such as open lines, strong posts, co-ordination of pieces; the last axis deals with the static and dynamic characteristics of pawn structure. Studying a few textbooks on chess strategy is certainly useful, but the benefits from additional material decrease rapidly. We recommend two or three classics (e.g., Euwe, 1972; Kmoch, 1980; Nimzowitsch, 1977), with the addition of a more recent textbook. Again, we believe that most of the strategic education can be gained by building one's own opening repertoire. In fact, quite a few opening books have taken this approach and attempt to illuminate the positional aspects arising from the opening under consideration. For example: Nunn's book on the Benoni (1982), Watson's book on the Tchigorin Defence (Watson, 1981), or, at a more popular level, Levy and O'Connel's book on the Sicilian Defence (1983).

In addition to studying textbooks, it is of course essential to learn and understand themes that are likely to occur in one's games. Here again, study of positions related to one's opening repertoire and repetition are key to progress.

4. Practical methods for acquiring and consolidating chess knowledge

We may divide practical methods into two broad categories: analytic methods and practice games. Under the first heading, we include activities such as analysis of openings, analysis of games (including one's own games), the decomposition method, and the technique of guessing the next move of a published game. The second heading addresses activities such as speed chess, games against computer, correspondence games, and training games. There is some overlap between the two categories: for example, the decomposition method can be coupled with speed chess or games against computer. As we have illustrated several of these methods in the preceding section, there is no need to repeat them here. However, a warning may be in order: teaching is a poor method of improving one's skill, because it directs attention to the wrong kind of material, from the point of view of a player aiming at improving his strength. In particular, teaching beginners and weak players can be particularly detrimental.

5. Methods not based on knowledge acquisition

We have hitherto described improvement techniques based on optimizing knowledge acquisition. Techniques focusing on other aspects of chess cognition have been proposed as well. We now review methods aimed at improving visual representation, short-term memory, and the ability to search ahead.

5.1. Practicing visual representation

Some authors have recommended practicing visual representation as a way to improve one's chess skills. However, while chess is obviously a visual and spatial game, there is no firm empirical data demonstrating the necessity of having strong general visual or spatial abilities in order to be a master. Indeed, available data suggest that general visuo-spatial abilities do not correlate with skill, and that these abilities are not more developed in chessplayers than in non-chessplayers (Waters, Gobet, & Leyden, in press). Given this lack of evidence, we do not encourage players to train this ability as such.

5.2. Practicing short-term memory

Again, there is no evidence showing that strong chess players have a superior STM capacity with material different from chess. Their superiority with chess material seems to be a side effect of the accumulation of large chunks. Therefore, there seems to be no need to train short-term memory in isolation.

5.3. Practicing the ability to look far ahead

This is one of the most contentious points of chess psychology and of chess training. According to our theory, the ability to look ahead is made possible by the co-ordination of LTM knowledge, STM, and visual imagery. The question for chess training is: which of these components to train, and how? In general, the theory indicates that good understanding of a position through pattern recognition should cut down the need for looking ahead.

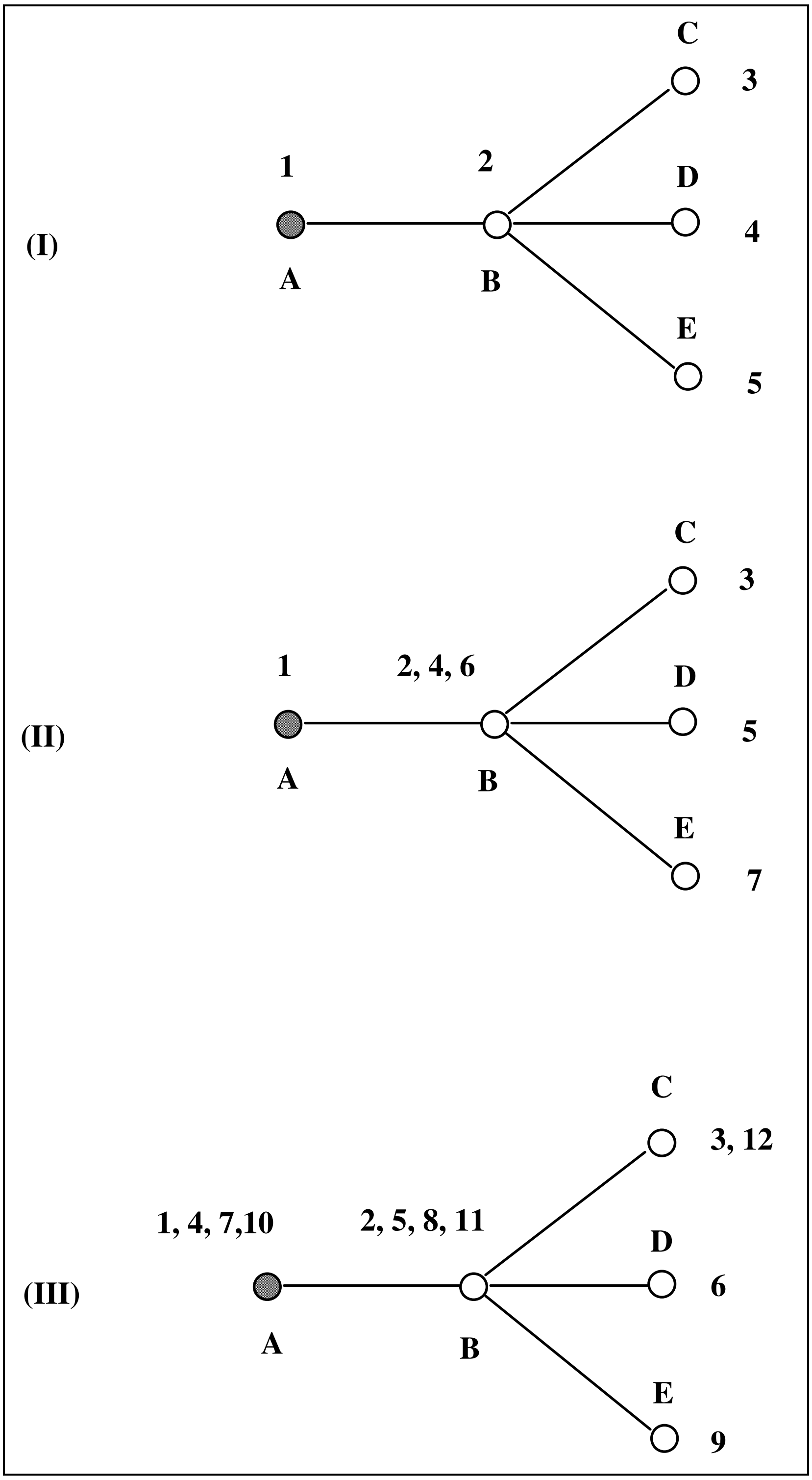

Figure 5: Illustration of various types of search. Humans typically use search depicted as III. Numbers indicate the sequence with which positions (indicated by letters) are visited.

Empirical research has shown that players tend to visit the same nodes several times (De Groot, 1978). For example, consider Figure 5, which depicts a search tree. The most economical way to search would be to visit every node only once (panel I). When considering position B, a player would then store the positions obtained after every move, and then analyze them in order. This would in general require a very large memory capacity, far beyond that of humans. Another approach is to come back to position B after having considered a terminal position, as shown in panel II. In this case, only one position (position B) has to be stored in memory, as opposed to the three positions of the first approach. What De Groot found in his classical study is that all players—including world-class grandmasters—tend to use a third approach. After having visited a terminal node, they come back to the root position (the position in plain view on the external board), and then play again the moves in their mind to reach another terminal position, possibly revisiting some nodes. This is shown in panel III. While this approach has the disadvantage of visiting more nodes than the previous approaches, it has the clear advantage of not overtaxing STM, and of reducing the risk of blundering or playing illegal moves due to errors in remembering the location of certain pieces (this is not a real danger in our example with a depth of only three half-moves, but is a real concern with larger depths). In addition, it allows the player to propagate the information gathered at a given node to other nodes. De Groot (1978; see also De Groot & Gobet, 1996) calls this search behavior “progressive deepening.”

It is worth pointing out that, even for improving depth of search, it is more efficient to improve one’s knowledge base than one’s ability to look-ahead. Assume that there are, on average, 35 legal moves in a position, each generating a new position or a new node in the search tree (cf. De Groot, 1978). Without knowledge, it is hard to decide among the possible choices. Assume also that a large amount of knowledge, encoded as chunks and templates, reduces this choice to 4 plausible moves, on average. Assume finally that a “fast searcher” looks at 20 positions per minute (i.e., 3 seconds per position), an “average searcher” looks at 6 positions per minute (i.e., 10 seconds per position), and a “slow searcher” looks at 2 positions per minute (i.e., 30 seconds per position).[5] Table 2 gives the average depth of search for various levels of search ability and knowledge, as defined above (a thinking time of 10 minutes is assumed).

---

[5] De Groot’s (1946/1978) data, as well as more recent data, indicate that players, including Masters and Grandmasters search about four or five moves in a minute, on

Search speed			Knowledge	
	Search rate (Nodes/minute)	Nodes searched in 10 minutes	Low Branching = 35 moves	High Branching = 4 moves
			Mean depth (in half-moves)	
Slow	2	20	0.8	2.2
Average	6	60	1.2	3.0
Fast	20	200	1.5	3.8

Table 2: Mean depth of search for an ideal player with or without knowledge, and with low, average, or high search abilities. Estimates are based on a thinking time of 10 minutes.

Assuming a search with constant depth, we find that weak players (slow search speed and low knowledge) increase their depth of search more by increasing their knowledge than their search ability. Players with low search speed but with high knowledge (that is, high selectivity) actually search deeper than players with high search speed but with low knowledge. Although the assumption of constant depth of search is not quite plausible, this demonstration makes our point clear: selective search due to knowledge is more useful than sheer search speed. In addition, searching without knowledge has a high likelihood of missing a good opportunity (something well known by chess program designers), because even fast searchers can cover only a very small portion of the search space.

Thus, training depth of search *per se* is unlikely to yield good results. Rather, depth of search should be seen as a consequence of acquiring a large knowledge base, which, through chunking of moves and creation of templates, leads to a more selective and efficient search.

Then, what to do with Kotov's (1971, 1983) famous advice of visiting each branch of the search tree only once? Certainly, Kotov has good intentions: put some order and organization into chess players' thoughts, which are often muddled indeed. Note that Kotov's techniques are not so much aimed at improving depth of search than at avoiding wasting time in analyzing a position.

---

average. All these experiments used verbal protocols, which may lead to an underestimation of the number of moves searched.

It is unclear what Kotov exactly means when he says (Kotov, 1971, p. 28— in bold in the text): "In analyzing complicated variations one must examine each branch of the tree once and once only." Is it valid only for terminal branches, or also for the intermediate branches between the initial position and the terminal branches? Take for example the case of a choice intervening after, say, 4 forced moves. Should the players never replay in their mind these first "introductory" moves? In addition, Kotov's advice of visiting each branch of the search tree only once is probably bad. As mentioned earlier, empirical evidence shows that even top-level players do visit the same branch several times, what De Groot calls "progressive deepening."

The fact remains that some players complain of searching in a disorganized way and of a lack of decision. But another technique proposed by Kotov (reducing the thinking time in training sessions), seems more appropriate to us: while inducing players to use their time gradually in a more structured and effective way, it will still leave time for those aspects of iterative deepening that are necessary for good decision making. When pushed to the extreme, this technique also provides a useful exercise for practicing play in time trouble.

6. Media of instructional materials

According to the chunking/template theory, the order of presentation of the material, as well as the way it is segmented, are crucial for effective training. Typically, it is unwise for a student to carry these tasks by himself: it is hard to do it efficiently, and it is time consuming. Therefore, it is important to have a good trainer, good computer software, or a good book, in order to have the instructional materials chopped into optimal chunks. Obviously, a trainer is more flexible than a book or than the computer programs currently available.

6.1. Role of coaches

A coach's contribution may be divided into two main aspects: a technical contribution, and a personal contribution. The technical contribution includes preparation of study materials and study programs, identification of the trainee's weaknesses and preparation of a program to fix them, feedback on games and results, and advice on how to play against the trainee's opponents, including preparation of specific variations. The personal contribution includes management of the trainee's motivation, and optimization of study time by reducing the time spent in administrative chores (e.g., looking for games belonging to the repertoire, subscription to tournaments, or decision about which competition to attend). Although the necessity of having a coach is sometimes debated (e.g., Charness, Krampe, & Mayr, 1996), we believe that it is a key factor of success—most grandmasters had a coach at some point of their career. Finally, research in education has shown that students take more advantage of a private tutor than from a tutor shared in a classroom (Bloom, 1984; Cohen, Kulik, & Kulik). We believe that this is the case with chess as well.

6.2. Textbooks

Books have been the main vehicle for transmitting chess knowledge. Whether they are also the optimal vehicle is a debatable question. Unfortunately, few of them follow recommendations inspired from sound psychological and pedagogical principles. For example, most books present schemata and methods specific to a small range of positions, which may not match the positions students will meet in their own practice, but offer the implicit promise that these schemata and methods will generalize to other positions. Learning these schemata and methods can be useful, of course—certainly if you play similar positions—but there is a serious danger for the students of believing that generalization will come easily. There is actually a paradox in most strategy textbooks: they advertise learning general principles, but actually, by using a "teaching-by-example" approach, communicate very specific methods.

In addition, most educational books have the default of placing diagrams either at the beginning of the game segment that will be discussed, or at some point where there is a tactical combination. Even books specifically devoted to strategy do not use diagrams to emphasize the constellations of pieces that are important to memorize. Obviously, from a pedagogical point of view, diagrams (and perhaps other visual aids) should be used to emphasize, reinforce, or help index the concepts being taught.

6.3. Computers

Today's computers offer an invaluable aid for creating and using game databases, for practicing with an opponent (computer or, on the internet, human), and for support with analysis of games and positions (e.g., Jansen & Schaeffer, 1990). In particular, we would recommend playing with a strong computer program to improve one's tactical skills, to practice typical positions (opening, middle game, endgame), and to test new ideas in openings.

We anticipate that the next generation of computer instruction will go beyond "merely" offering facilities for playing and managing databases, and will also act as a real coach. For example, it could select the study material (tactical positions, strategic themes, endgames, etc.) as a function of the strengths and weaknesses of the student. Similar technology has been recently developed in domains such as the teaching of geometry or programming (Anderson et al., 1995).

7. Summary and conclusion

In this chapter, we have applied a scientific theory of chess expertise to the question of chess training.[6] The theory emphasizes that skill is derived from the creation of chunks (perceptual knowledge units) and templates (conceptual knowledge units), and that search ability directly depends upon them. In general, the practical pieces of advice inspired by the theory stress the necessity of building knowledge that will likely be of use in future games. This is achieved by centering knowledge acquisition around one's opening repertoire, including knowledge about middlegames, endgames, tactics and strategy. A few techniques are discussed, such as the decomposition method. Not surprisingly, applying such a training approach is time consuming—it takes years to become a master. We finally hinted at some possible developments in educational computer technology, which may lead to new powerful chess tutoring programs.

What will be required at the next step of chess training, to advance from Master to Grandmaster? In short: more of the same. The differences are mainly of degree: a player's opening preparation becomes more and more detailed, with increasing emphasis on specific cases; their opening repertoire widens, and their ability to cope with unknown middlegame and endgame positions increases. The added difficulty—a serious one—is to maintain motivation during the long years of study and practice. The advance to higher levels is not always smooth, and may be punctuated by periods without noticeable improvement, or even relative decline. Only the player with the will power to overcome these motivational hurdles will manage to make it to full mastery.

---

[6] There are obviously a number of topics we have not addressed in this chapter, such as training for endurance, the psychology of errors, playing the opponent (e.g., Krogius, 1976; Kotov, 1971; Munzert, 1990). While these are important questions, the fact is that they are even less well understood than the topics we have discussed.

References

Anderson, J. R. (1990). *Cognitive psychology and its implications* (3rd ed.). New York: Freeman.

Anderson, J. R., Corbett, A. T., Koedinger, K. R., & Pelletier, R. (1995). Cognitive tutors: Lessons learned. *The Journal of the Learning Sciences, 4*, 167-207.

Awerbach, J. (1981a). *Lehrbuch der Schachendspiele (Band 1).* Berlin: Sportverlag.

Awerbach, J. (1981b). *Lehrbuch der Schachendspiele (Band 2).* Berlin: Sportverlag.

Binet, A. (1894). *Psychologie des grands calculateurs et joueurs d'échecs*. Paris: Hachette. [Reedited by Slatkine Ressources, Paris, 1981.].

Bloom, B. S. (1984). The 2-sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*, 4–16.

Bönsch, E. (1987). *Schachlehre für Lehrende und Lernende* (2 ed.). Berlin: Sportverlag.

Capablanca, J. R. (1963). *A primer of chess*. New York: Harcourt, Brace, & Cie.

Charness, N., Krampe, R., & Mayr, U. (1996). The role of practice and coaching in entrepreneurial skill domains: An international comparison of life-span chess skill acquisition. In K. A. Ericsson (Ed.), *The road to excellence* (pp. 51-80). Mahwah, NJ: Lawrence Erlbaum.

Chéron, A. (1942). *Nouveau manuel d'échecs du débutant*. Paris: Payot.

Cohen, P. A., Kulik, J. A., & Kulik, C. L. C. (1982). Education outcomes of tutoring: A meta-analysis of findings. *American Educational Research Journal, 19*, 237–248.

De Groot, A. D. (1946). *Het denken van den schaker*. Amsterdam: Noord Hollandsche.

De Groot, A. D. (1978). *Thought and choice in chess* (Revised translation of De Groot, 1946; 2nd ed.). The Hague: Mouton Publishers.

De Groot, A. D., & Gobet, F. (1996). *Perception and memory in chess. Heuristics of the professional eye*. Assen: Van Gorcum.

Dvoretzky, M., (1991). *Secrets of chess training*. London: Batsford.

Ericsson, K. A., & Staszewski, J. J. (1989). Skilled nemory and expertise : Mechanisms of exceptional performance. In D. Klahr & K. Kotovski (Eds.), *Complex information processing: The impact of Herbert A. Simon.* Hillsdale, NJ: Lawrence Erlbaum Ass.

Euwe, M. (1962). *Die Endspiellehre und ihre praktische Anwendung*. Hamburg: Schach-Archiv.

Euwe, M. (1972). *Les échecs: jugement et plan*. Paris: Payot.

Gagné, R., Briggs, L. J., & Wagner, W. W. (1989). *Principles of instructional design*. New York, NY: Holt, Rinehart, & Winston.

Gobet, F. (1993). *Les mémoires d'un joueur d'échecs*. Fribourg (Suisse): Editions Universitaires.

Gobet, F., de Voogt, A., & Retschitzki, J. (in press). *Moves in mind*. Hove: Routledge/Psychology Press.

Gobet, F., & Simon, H. (1996). Templates in chess memory: A mechanism for recalling several boards. *Cognitive Psychology, 31*, 1-40.

Gruber, H., & Strube, G. (1989). Zweierlei Experten : Problemisten, Partiespieler und Novizen bei Lösen von Schachproblemen. *Sprache & Kognition, 8*, 72-85.

Holding, D. H. (1985). *The psychology of chess skill*. Hillsdale, NJ: Erlbaum.

Jansen, P.J., & Schaeffer, J. (1990). On seconding a grandmaster, *ICCA Journal, 13*, 29-33

Keres, P., & Kotov, A. (1964). *The art of the middle game*. New York, NY: Dover.

Kmoch, H. (1980). *La force des pions aux échecs. [Pawn power in chess]*. Paris: Payot.

Kotov, A. (1971). *Think like a grandmaster*. London: Batsford.

Kotov, A. (1983). *Chess tactics*. Macon, GA: American Chess Promotion.

Krogius, N. (1976). *Psychology in chess*. London: R.H.M Press.

Levy, D., & O'Connel, K. J. (1983). *Comment jouer la défense sicilienne*. Paris: Grasset.

Mednis, E. (1979). *Practical endgame lessons*. London: Batsford.

Munzert, R. (1990). *Schachpsychologie*. Hollfeld: Beyer.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Nimzowitsch, A. (1977). *My system. A chess treatise.* London: Bell & Sons.

Nunn, J. (1982). *The Benoni for the tournament player*. London: Batsford.

Pachman, L. (1972). *Modern chess strategy*. New York, NY: Dover.

Pachman, L. (1977). *Les finales*. Paris: Payot-Diffec.

Saariluoma, P. (1995). *Chess players' thinking: A cognitive psychological approach*. London: Routlege.

Shereshevsky, M. (1994). *Endgame strategy*. New York, NY: Macmillan.

Simon, H. A., & Chase, W. G. (1973). Skill in chess. *American Scientist, 61*, 393-403.

Travers, M. W. (1978). *An introduction to educational research.* New York, NY: Macmillan.

Waters, A., Gobet, F., & Leyden, G. (in press). Visuo-spatial abilities in chess players. *British Journal of Psychology*.

Watson, J. L. (1981). *Queen's Gambit: Chigorin Defense*. London: Batsford.

Acknowledgments

We thank Guillermo Campitelli and Peter Lane for useful comments on this chapter.