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Effect of expertise acquisition on strategic perception: The example of chess

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The two experiments presented here study perceptual processes implemented by chess players in situations related to their domain of expertise. The aim was to determine how patterns are perceived as a function of their strategic value when players acquire expertise. In this study, conducted on novice and more experienced players, it is hypothesized that with acquisition of expertise players would quickly encode familiar patterns and then rapidly focus their attention on patterns with a higher immediate strategic value. In Experiment 1, participants had to carry out a change-detection task that used the "flicker paradigm". The results showed that during the perception of standard chess positions, experienced players—but not novices—quickly focused their attention on the most strategic patterns. In Experiment 2, experienced players and novices carried out a recognition task after having encoded chess positions for 1 or 5 s. The results indicated early encoding of familiar patterns without immediate strategic value, followed by the encoding of more strategic patterns. Taken together, the results of these two experiments are consistent with the results by both de Groot and Gobet (1996) and McGregor and Howes (2002) about the strategic content of Chase and Simon's chunks (Chase & Simon, 1973b).

It is now well established that expertise in a given knowledge domain is largely based on experts' ability to store a very large number of "chunks" or typical patterns in long-term memory (LTM; for chess, see, for example, Chase & Simon, 1973a, 1973b; de Groot, 1965; for a review, see Gobet, 1998; Gobet & Charness, 2006; Gobet, de Voogt, & Retschitzki, 2004). However, studies on the content of these chunks and how they are recognized and encoded are scarce (McGregor & Howes, 2002). This article looks precisely at how the different patterns present in a chess position are encoded according to their immediate strategic value. It is hypothesized that experienced players begin encoding a position by visually processing familiar patterns—patterns on their original undeveloped positions (i.e., rows 1, 2, 7, and 8, here after called "undeveloped")—and then quickly go on to analyse patterns that have the most immediate strategic value—directly linked to the next move (here after called "developed"). Note here that our experienced

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players had only 1,729 Elo points in average, but we expected that chess players used the visual processes studied here very early in their expertise acquisition. In Experiments 1 and 2, these hypotheses are tested using a perception-study paradigm (i.e., the flicker paradigm) and a recognition task.

Since the original work by de Groot (1965) and Chase and Simon (1973a), many studies have shown that when experts and novices have to recall a chess board situation, experts outperform novices (Ericsson & Staszewski, 1989; Gobet & Simon, 1996a). This finding is usually explained by the fact that expert players have already built and stored a large number of chunks in LTM, and this enables them to recognize or recall chess situations more quickly and more accurately than do novices. According to Chase and Simon, the fundamental component of chess expertise lies in the perceptual advantage of experts, which the authors describe principally in terms of their ability to recognize not only perceptual chunks, but also strategic chunks (Newell & Simon, 1972). An analysis of the protocols collected by Chase and Simon showed indeed that virtually all of the chunks reconstructed by expert participants fell into one of the following three categories: sets of same-colour pieces from the first row on each side of the chessboard (rows 1 and 8), often in their original undeveloped positions; castled-king configurations; and chains of pawns. These three categories encompass what Chase and Simon called perceptual chunks (see Figure 1 for an example of an undeveloped chunk and a developed one).

Chase and Simon (1973a) also mentioned another kind of perceptual chunk (infrequently found in expert reconstructions) that illustrates the link between the type of chunk and strategic information—namely, classic configurations of attacking pieces all heading toward the opponent's castled-king configuration or some other vulnerable point. The pieces in chunks of this type are related in numerous ways both to each other and to the rest of the pieces on the board. In certain cases, this type of chunk can provide information about the best move that can be made. These different types of chunks do not have the same strategic value (McGregor & Howes, 2002). For example, while a chunk corresponding to a chain of pawns in their original undeveloped positions can be readily encoded as a familiar pattern, this type of chunk supplies little strategic information. In contrast, the activation of a chunk corresponding to the same chain of pawns in a strategic location (e.g., close to the opponent's camp) integrates more strategic information, since the number and position of the pawns on the chessboard are a reliable indication of the strength or weakness of a game position (Gobet, 1998).

Figure 1. *Examples of two types of chunks: undeveloped (dotted circle) and developed (full circle).*

In short, the different types of chunks can differ widely in their strategic value. The opposition between chunks with an immediate low or high strategic value is common in the literature on chess expertise. Charness (1976), for example, proposed what he called "familiar" and "meaningful" chunks (for a study using quasi-random positions that supports this distinction, see Schultetus & Charness, 1999). Likewise, there are many studies suggesting that knowledge in expert memory contains more semantic information than in the "perceptual" chunks described by Chase and Simon (Didierjean & Marmèche, 2005; Ferrari, Didierjean, & Marmèche, 2006; Gobet & Simon, 1996b; Goldin, 1978; Lories, 1987; McGregor & Howes, 2002).

Studies on eye movements of players as they analyse chess positions have shown that the extent to which a player looks at different areas of a chessboard depends upon the strategic value of the pieces located there. Jongman's (1968) data showed that experts rarely looked at portions of the board where they recognized a familiar pattern. On the other hand, they spent a lot of time looking at areas containing highly strategic information. According to Jongman, the strategic value of a piece or pattern of pieces depends on how close it is to the opponent's camp, especially at the beginning or middle of a game. De Groot and Gobet (1996) replicated these results by showing that experts can almost perfectly recall portions of a position seen for only a very short time. In their eye-movement analyses of the visual exploration of game configurations in a memory task, these authors found that expert players looked very little at "familiar" areas of the chessboard—that is, the outer edges containing typical patterns (e.g., chains of hardly moved pawns, castled-king positions). Experts may quickly set these "normal" areas aside in order to focus on the more strategic zones in the middle of the board. For de Groot and Gobet (1996), this tactic is grounded on the general heuristic, "Don't waste time on anything that's normal". One of the criteria they define for assessing the importance of a pattern of pieces is how close it is to the opponent's camp (a definition similar to the one in Jongman's, 1968, "exposed piece" hypothesis).

De Groot and Gobet (1996) also suggested that pattern encoding varies with the pattern's strategic value. First, experts would perceive the whole position, taking into account few specific cues. These cues (for instance, the position or colour of certain pieces) may suffice for activating an entire perceptual chunk in LTM. Concerning the more strategic configurations, experts set a more complete and detailed encoding, in order to grasp all important chess relations among the pieces. A study by Reingold, Charness, Pomplun, and Stampe (2001a) also argues for a nondetailed encoding of certain chunks. The eye-movement analysis in their study showed that the majority of the experts' eye fixations were "between" rather than "on" the pieces of familiar patterns. The patterns used in their experiment were presented on a 9-square chessboard (3×3 squares) on which one or two of the opponent's pieces (depending on the condition) could potentially put the king in check. The familiarity of the patterns used (frequently near the end of a game), the simplicity of the chess relation at stake (putting the king in check), and the small size of the chessboard allowed experts to implement automatized, rapid, low-level processes to encode the familiar patterns and activate the corresponding perceptual chunks in LTM. The study by Charness, Reingold, Pomplun, and Stampe (2001) was also based on an eye-movement analysis, but their chess positions were standard (the whole chessboard was used). Their results showed that the experts' first fixations were very often on empty squares, which is indicative of the involvement of parafoveal and peripheral perception processes, and that already within the first few seconds of position exploration, most of the eye fixations were on strategically important pieces.

The purpose of the two experiments reported here was to supplement the findings obtained in eye-movement research on experts. Our study was aimed at improving our understanding of the temporal course of perceptual processes used by experienced players and novices to encode chess positions.

In Experiment 1, the "flicker paradigm" was used. In this paradigm (Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997; Simons & Rensink, 2005) an original image and a modified image of a scene are presented in rapid alternation with a grey screen interposed between them, giving the display a flickering appearance. The cycle of alternation repeats until observers report the change, and response latency is used as a dependent measure of change blindness. In our study, the participants' task was to detect changes made either in undeveloped patterns (on their original position) with a low strategic value, or in developed patterns with a high strategic value (determined on the basis of their position in the middle of the chessboard and/or close to the opponent's camp). If as empirical results of eye-movement studies suggest, experienced players first start by encoding undeveloped patterns in a rapid and nondetailed way, a change occurring in the first seconds will not be perceived. In addition, if experienced players go on to encode developed patterns in a detailed way, one can expect them to detect changes in these patterns more rapidly and accurately than changes in undeveloped patterns.

Experiment 2 was aimed at gaining further information on pattern encoding during the first few seconds of chessboard exploration. After a one- or five-second display of a position, participants had to make a recognition judgement about whether various small configurations were in the position just seen. The hypothesis tested was that during the first second of exploration, experienced players encode undeveloped patterns and will therefore more easily recognize those configurations than more strategic patterns. On the contrary, in the five-second condition, it was hypothesized that experienced players would focus their attention on the most strategic patterns, analysing them carefully enough to later recognize them and differentiate them from new patterns.

EXPERIMENT 1

The aim of Experiment 1 was to test the hypothesis that during the visual exploration of a standard position of a chess game, experienced players focus very rapidly their attention on patterns that have the most strategic value. The experimental technique used was the flicker paradigm to study "change blindness" (Rensink et al., 1997). This technique was applied to a comparison task on standard chess-game positions. Participants who were chess novices or experienced players had to decide as quickly and accurately as possible whether two positions presented in alternation were the same or different. When the positions were different, the difference concerned only one piece, which was part of an "undeveloped" pattern or of a "developed" pattern. The following distinction was made here between patterns called "undeveloped" and patterns called "developed": Undeveloped patterns were located in a typical place on the chessboard (e.g., chains of pawns on their starting squares) that did not play an immediate strategic role. The same pattern (i.e., same chains of pawns) was considered more strategic when it was located close to the opponent's camp and therefore includes more strategic relations (see de Groot & Gobet, 1996; Jongman, 1968). In order to validate the distinction between undeveloped and developed patterns, four experienced players (Expert 1: 2,000 Elo; Expert 2: 2,100 Elo; Expert 3: 2,100 Elo; master: 2,400 Elo) were asked to rate the immediate strategic value of each pattern on scales ranging from 0 to 5. Undeveloped patterns were indeed judged with a low immediate strategic value (mean rating on the strategic scale 1–10). Developed patterns were judged as having a high immediate strategic value (mean strategic rating 3.53). These scores validated our distinction between undeveloped versus developed patterns. Details on the experts' judgements are presented in Appendix A.

Given the conditions under which the to-be-explored positions were presented here (i.e., using the flicker paradigm), and the relative inconspicuousness of the changes made (i.e., only one piece moved) our predictions were as follows. First, novices, who have few chunks in LTM, would detect changes less well than experienced players. In addition, changing an undeveloped or a developed pattern should not make a difference for novices since this distinction is not yet meaningful to them. Furthermore, if experienced players would encode undeveloped patterns in a nondetailed way (this kind of encoding not being very effective to detect changes), one can expect experienced players should be faster and better at detecting changes in developed patterns (encoded in a detailed way) than in undeveloped patterns.

Method

Participants

A total of 40 participants took part in the experiment (mean age: 25 years, standard deviation 6 months). Of these, 20 were experienced players. These experienced players were Class B players (mean number of Elo points: 1,729; standard deviation: 200 points). The other 20, called "novices", knew the rules of the game and played chess about five times a year for a minimum of 5 years. Note that a typical beginning tournament player has a low rating (close to 1,200 Elo points), whereas a national master has at least 2,200 Elo points (Kasparov had more than 2,800 Elo points in the 90s).

Materials

Familiarization phase. The material for the familiarization phase included 6 pairs of chess positions: 4 "different" pairs and 2 "same" pairs. The aim of the familiarization phase was to give the participants an opportunity to warm up to the experimental procedure.

Experimental phase. The materials for the experimental phase included 35 pairs of chess positions: 7 "same" pairs and 28 "different" pairs. Seven reference positions (seven prototypical opening positions) were used to generate the position pairs. The reference position was always presented first in each pair. The reference positions were standard positions of a chess game after an average of 10 moves. In the same pairs, the reference position was presented twice. In the different pairs, the identity but not the colour of a single piece was changed (e.g., a pawn was changed into a bishop). Depending on the experimental condition, the changed piece belonged either to a undeveloped pattern or to a developed pattern. A undeveloped pattern was considered familiar when it was in a typical location on the chessboard (e.g., a chain of pawns close to their original squares, a set of same-colour pieces that often remain in their original positions) and contained little strategic information for the current game. A developed pattern was considered strategic when it was close to the opponent (e.g., a chain of pawns moved quite far forward into the opponent's camp). All of the positions included both undeveloped and developed patterns. For each of the seven starting configurations, the modification of a pattern (undeveloped or developed) was made once on the black pieces and once on the white pieces.

Procedure

The experiment was run on a Macintosh PowerBook G3 computer. The participant's task was to determine as quickly and accurately as possible whether the chess positions in the pairs presented were the same or different. The two positions in each pair were presented repeatedly, one after the other, using the flicker paradigm technique. All presentations were cyclical. Before each cycle, the message "Ready?" appeared on the screen, and the participant had to press any key to begin. A cycle consisted of the following sequence. A fixation point was displayed mid-screen for 1,000 ms. The first position ("D") was then shown for 1,000 ms, followed by a 100-ms mask (a rectangular opaque mask with the same dimension as the display positions). Next, the second position ("Dm") was displayed for 1,000 ms, also followed by a mask. The first position was then presented again on the screen, and so on. The D−mask−Dm−mask cycle ended when the participant responded by pressing the "same" key on the left of the keyboard or the "different" key on the right of the keyboard. Participants who answered "different" had to say aloud which piece they thought had been changed (given that all responses were correct, no further analyses were conducted on the changed pieces). All participants underwent an initial familiarization phase consisting of six trials: four with different pairs and two with same pairs. They were informed that their response time would not be recorded during familiarization. In all conditions, the position pairs were presented in a different random order for each participant.

Results and discussion

After averaging the two types of "different" pairs (pairs where an undeveloped pattern was changed and pairs where a developed pattern was changed), a first analysis of variance (ANOVA) was conducted on the correct-detection rates. The results indicated a higher correct-detection rate for same comparisons, respectively 99.29% for experienced players and 99.24% for novices, than for different comparisons, respectively 85.02% for experienced players and 58.20% for novices. The difference was significant, $F(1, 38) = 182.76$, $MSE = 85.48$, $p < .01$. A second ANOVA was conducted on the correct-detection latencies. The results also showed that the correct-detection latencies were longer for same comparisons, respectively 14.35 s for experienced players and 13.32 s for novices, than for different comparisons, respectively 6.11 s for experienced players and 8.97 s for novices. The difference was significant, $F(1, 38) = 30.28$, $MSE = 24.63$, $p < .01$.

For different comparisons, two ANOVAs were run on the correct-detection rates and correct-detection latencies, with the type of pattern (undeveloped vs. developed) as a within-subject factor and the expertise level (experienced players vs. novices) as a between-subject factor.

Correct-detection rate

The correct-detection rate was significantly higher for experienced players (85%) than for novices (57.86%), and for developed patterns (76.78%) than for undeveloped patterns (66.07%). The results indicated significant effects of expertise, $F(1, 38) = 47.58$, $MSE = 80.09$, $p < .01$, and type of pattern, $F(1, 38) = 28.72$, $MSE = 80.09$, $p < .01$. The correct-detection rate for experienced players on undeveloped patterns (74.29%) was significantly lower than it was on developed patterns (95.71%) (see Figure 2). A significant interaction between the type of pattern and the expertise level was observed, $F(1, 38) = 28.72$, $MSE = 80.09$, $p < .01$. The type-of-pattern effect was significant for the experienced players, $F(1, 19) = 86.51$, $MSE = 53.18$, $p < .01$, but not for the novices, $F(1, 19) < 1$, $MSE = 107$.

Correct-detection latencies

The effect of extreme latencies was minimized by setting a cut-off of two standard deviations above and below the mean for each participant. All extreme values were eliminated from the analyses (5%). The correct-detection latencies were significantly longer for undeveloped patterns (8.71 s) than for developed patterns (6.85 s). The results yielded a significant effect of the type of pattern, $F(1, 38) = 45.19$, $MSE = 1.53$, $p < .01$. The expertise effect was nonsignificant, $F(1, 38) = 2.31$, $MSE = 1.53$, $p > .05$, but there was a significant interaction between the type of pattern and the expertise level, $F(1, 38) = 13.69$, $MSE = 1.53$, $p < .01$. The correct-detection latencies of experienced players were longer for undeveloped patterns (8.63 s) than for developed patterns (5.74 s; see Figure 2b). This difference between the correct-detection latencies of undeveloped and developed patterns was significant for experienced players, $F(1, 19) = 65.51$, $MSE = 1.27$, $p < .01$, but not for novices, $F(1, 19) = 3.90$, $MSE = 1.79$, $p > .05$.

Note that the mean times observed here are very similar to those obtained by Reingold et al. (2001a) in a flicker paradigm task. Their mean detection time was about 6.5 s for experienced players, compared to the 7.2 s obtained by the experienced players in our study. Their novices had a mean detection time of 7.5 s versus 7.78 s for novices in our study.

Correct detections over time

Kolmogorov–Smirnov's nonparametric test was applied to the distribution over time of correct detections for each type of pattern (undeveloped vs. developed) for experienced players and novices. Figure 3 presents the correct-detection rates as a function of display time for developed and undeveloped pattern changes.

Results indicated a significant difference for experienced players (see Figure 3a) between the correct-detection distributions of undeveloped and developed patterns ($D = .364$, $p < .01$). We performed a sign test for two related samples to compare detection of undeveloped and developed items second by second. The results showed that the correct-detection rate of developed patterns was significantly greater than that of undeveloped patterns at 3 seconds ($Z = 15.90$; $p < .01$) and at 4 seconds ($Z = 9.59$; $p < .01$). This result pattern was reversed at 9 seconds ($Z = 15.90$; $p < .01$) and at 10 seconds ($Z = 15.90$; $p < .01$), where the correct-detection rate was marginally greater

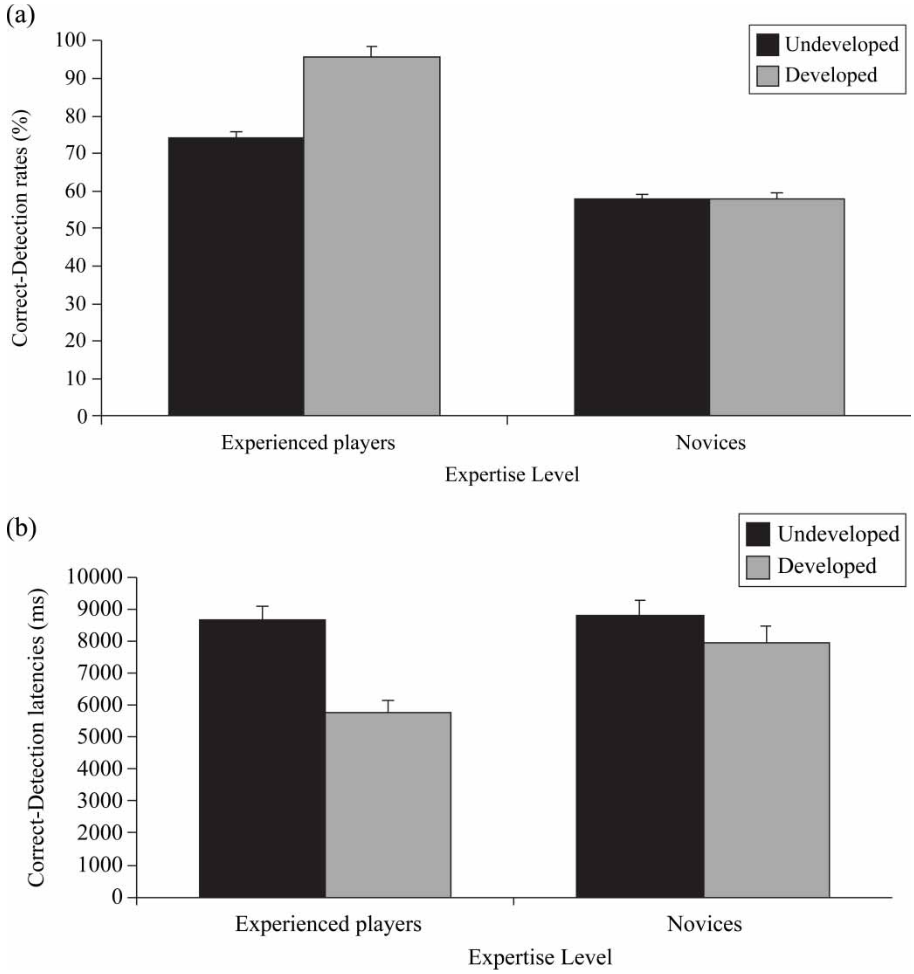

Figure 2. *(a) Correct-detection rates and (b) correct detection latencies of experienced players and novices, by type of pattern modified (undeveloped vs. developed). Error bars represent the standard error.*

for undeveloped patterns than for developed patterns (for the other seconds, no significant difference was observed). For the novices (see Figure 3b), the undeveloped pattern distribution over time was quite similar to the developed pattern distribution ($D = .111$, $p > .05$). For experienced players and novices as well, most correct detections took place before the fifth second. In addition, experienced players and novices made little correct detection before the third second—that is, at the beginning of the second cycle of presentation.

In sum, the results of this first experiment bring out two critical points. (a) As a whole, the experienced players detected differences better than the novices did, no matter where the changes occurred (in undeveloped or developed patterns). This result is in line with classic findings showing the perceptual advantage of experts over novices. The expert advantage can be explained by their use of the many chunks they possess, which allows them to maximize the effectiveness of their visual exploration strategy (Chase & Simon, 1973b; Ericsson & Staszewski, 1989; Gobet & Simon, 1996a;

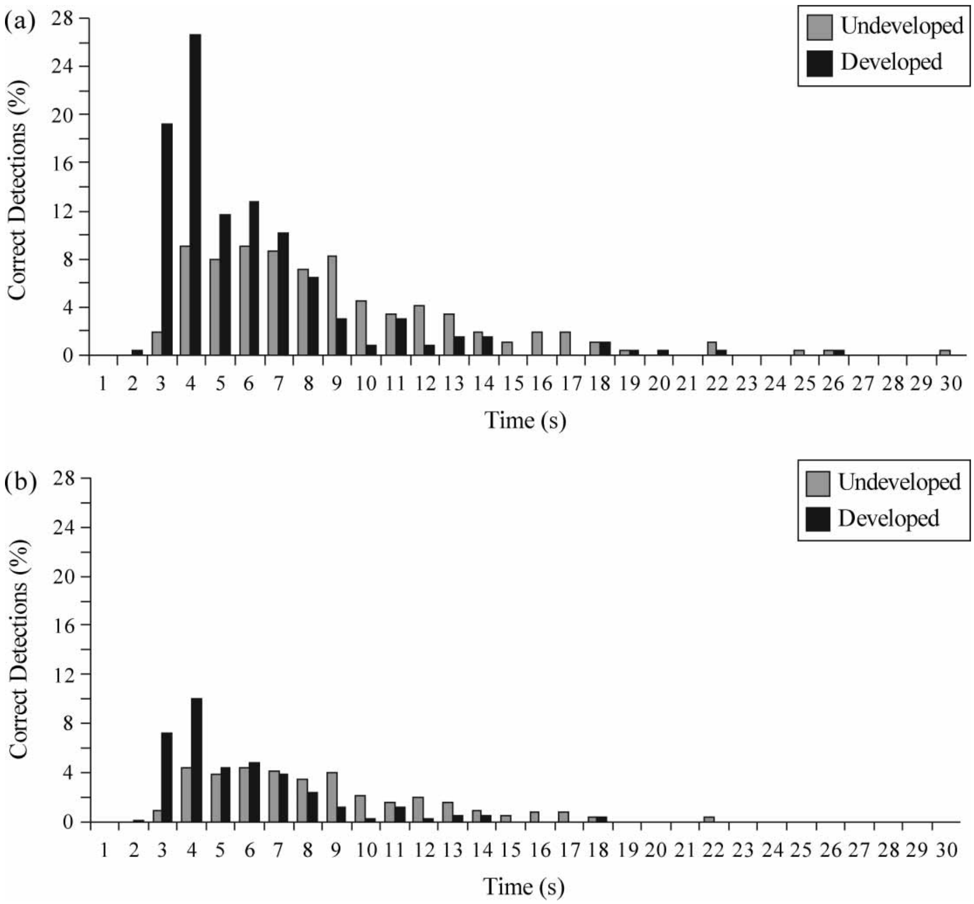

Figure 3. *Distribution of correct detections over time: Correct detections (%) by (a) experienced players and (b) novices as a function of time of presentation for undeveloped and developed patterns.*

Holding & Reynolds, 1982; Reingold, Charness, Schultetus, & Stampe, 2001b). (b) The performance of the experienced players, but not of the novices, differed significantly according to whether the changes were in undeveloped or developed patterns: The change-detection rate was higher on developed patterns than on undeveloped patterns, and correct detections were also faster for patterns that were developed. For experienced players, the majority of the correct detections on developed patterns took place before the fifth second (45% around 3–4 s). These results show that the strategic value of chess patterns plays a crucial role in game-position exploration by experienced players. They support the hypothesis that experienced players focus quickly on the patterns that are the most important from a strategic point of view. The aim of Experiment 2 was to determine how chess positions are encoded, at the first and the fifth seconds of exploration.

EXPERIMENT 2

The purpose of this experiment was to gain insight into how chess positions are encoded by experienced players during the first seconds of visual exploration. The hypothesis tested was that in the first few seconds of exploration, experienced players focus their attention on the undeveloped patterns in the position presented. By identifying these patterns, the experienced players "set the stage" for the current situation. It is not until this initial scrutiny is completed that attention is directed toward the areas with the greatest strategic value, which are given top priority for deciding on a plan of action.

A recognition task was devised to test this hypothesis. A series of chess positions were presented. After each position, four small configurations (two pieces) were displayed in succession. The participant had to determine whether the small configuration was in the position just seen. Some of the small configurations were in fact taken from the position and were part of either an undeveloped or a developed pattern. Others were new patterns (undeveloped or developed) from other chess positions. To assess how the visual exploration process used by experienced players and novices evolves over time, two display conditions were defined: The chess position display time was either one second or five seconds.

Based on our hypothesis—namely, that the visual exploration of experienced players begins with the identification of undeveloped patterns—one can predict that, in the one-second condition, the number of hits would be higher on undeveloped patterns than on developed patterns. The opposite result is expected in the five-seconds condition, the attention of the experienced players being mainly centred on the most developed patterns. By contrast, for the novices, we predict that in the one-second condition, they will have no time to encode the positions and will therefore respond by chance. In the five-seconds condition, novices would focus their attention on undeveloped patterns, which are the most available in long-term memory.

Method

Participants

A total of 80 participants took part in the experiment (mean age: 28 years 3 months, standard deviation: 5 years). A total of 40 of them were experienced players (Class B and Class A players,[1] mean number of Elo points: 1,792; standard deviation: 160 points). The other 40, called "novices", knew the rules of the game and played chess about five times a year.

Materials

Familiarization phase. The familiarization materials included one chess position and four small configurations of pieces. Two of the configurations were in the chess position.

Experimental phase. (see Appendix B for examples). The experimental materials included six chess positions and four small configurations per position. Among the four configurations, two were in the position, and two were from other chess positions. The positions presented in this phase were six of the seven chess positions used in Experiment 1 (the seventh position was used for familiarization). The Experiment 2 configurations were the undeveloped and developed patterns of the six Experiment 1 positions.

Procedure

The experiment was run on a Macintosh PowerBook G3 computer. The task was a recognition task. The participants were shown standard chess positions and were asked to memorize them as well as possible. The position-display time was one or five seconds, depending on the experimental condition. The experienced players and novices were divided into four groups. In the one-second display condition, there was one group of 20 experienced players (mean number of Elo points: 1,807; standard deviation: 198 points) and one group of 20 novices; in the five-second display condition, there was one group of 20 experienced players (mean number of Elo points: 1,777; standard deviation: 113 points) and one group of 20 novices. Each position studied was followed by four small configurations presented in succession. Two of the four were from the memorized

[1] Given that the results were similar for Class A and Class B players, the results for these two populations are presented together.

Table 1. *Mean values of d′ and c for experienced players and novices, by type of patterns and display condition*

	Experienced players				*Novices*			
	1 second		*5 seconds*		*1 second*		*5 seconds*	
Type of pattern	*d′*	*c*	*d′*	*c*	*d′*	*c*	*d′*	*c*
Undeveloped	1.40	−1.18	0.56	−0.15	0.43	−0.02	0.76	−0.09
Developed	0.32	0.86	1.69	−0.09	0.99	0.51	0.71	0.62

position and are hereafter called "old items"; the other two were taken from another chess position and are hereafter called "new items". Two of the four configurations were undeveloped patterns, and two were developed patterns. Thus, the four configurations presented for each position in the recognition task were: one old undeveloped pattern, one new undeveloped pattern, one old developed pattern, and one new developed pattern. Note that the two new items (an undeveloped pattern and a developed pattern) were "new" with respect to the chess position just presented, but they were part of a position displayed on another trial (before or after). With this setup, the patterns used in this experiment had the same degree of familiarity and the same strategic value for all chess positions presented. The participants' task was to determine as quickly and accurately as possible whether each of the four configurations was present in the position. After each configuration, the participants had to estimate their degree of confidence in their response by answering yes or no to the question "Are you sure of your answer?" After these questions, the next position to be memorized was displayed. Six positions were presented in random order to all participants, each one followed by the four small configurations associated with it.

Results and discussion

An analysis based on Signal Detection Theory (SDT) was used to analysis the data (see Appendix C for the percentage of hits and false alarms).[2] Two ANOVAs were run on d' and c with the type of pattern (undeveloped vs. developed) as a within-subject factor, and the expertise level (experienced players vs. novices) and the display condition (1 vs. 5 s) as between-subject factors. Table 1 gives the mean values of d' and c for experienced players and novices, by type of item (undeveloped or developed) and display condition (1 s or 5 s).

Concerning d', the results of the ANOVA showed a significant three-way interaction between the type of pattern, the level of expertise, and the display condition, $F(1,\ 76) = 21.13$, $MSE = 0.93$, $p < .01$. Concerning c, the results indicated a significant three-way interaction between the type of pattern, the level of expertise, and the display condition, $F(1, 76) = 38.13$, $MSE = 0.30$, $p < .01$. The following results present the planned comparisons by the level of expertise.

Experienced players

Results showed that within the first second, the experienced players discriminated undeveloped

[2] SDT is a model of recognition memory in which a participant attempts to distinguish two kinds of stimuli: new (N) and old (O). These stimuli evoke not single memories, but their Gaussian distribution on a decision axis of familiarity. The observer's ability to tell stimuli apart depends on the overlap between the distributions of O and N stimuli, quantified by d', the normalized difference between their means. The goal of identifying each stimulus as an example of N or O is based on a criterion (c) value of the decision axis. The placement of the criterion determines both the hits ("yes" responses to O) and the false alarms ("yes" responses to N). If the criterion is high (strict), the participant will make few false alarms, but also not many hits. By adopting a lower (more lax) criterion, the number of hits is increased, but at the expense of also increasing the false alarm rate. This change in the decision strategy does not affect d', which is therefore a measure of discriminability between O and N stimuli that is independent of response bias (decision criterion c).

pattern ($d' = 1.40$) better than developed pattern ($d' = 0.32$), $F(1, 19) = 11.76$, $MSE = 0.99$, $p < .01$. When the display time was five seconds the experienced players discriminated developed pattern more than undeveloped pattern ($d' = 1.69$ for developed patterns, $d' = 0.56$ for undeveloped patterns), $F(1, 19) = 16.38$, $MSE = 0.77$, $p < .01$. In addition, in the one-second display condition, the experienced players' decision criterion on undeveloped patterns was less (c $= -1.18$) than that on developed patterns (c $= 0.86$), $F(1, 19) = 80.05$, $MSE = 0.52$, $p < .01$.

Novices

The results for the novices were different. Concerning d', no significant difference was observed between undeveloped and developed patterns either in the one-second condition, $F(1, 19) = 2.50$, $MSE = 1.26$, $p > .05$, or in the five-seconds condition, $F(1, 19) < 1$, $MSE = 0.72$, $p > .1$. Nevertheless, the results indicated that the novices' decision criterion (c) was lesser on undeveloped patterns than on developed patterns, whether in the one-second display ondition, $F(1, 19) = 15.35$, $MSE = 0.19$, $p < .01$, or in the five-seconds display condition, $F(1, 19) = 15.77$, $MSE = 0.32$, $p < .01$.

Summary

These results support our main hypothesis—that is, in the first few seconds of exploration, the visual attention of experienced players is directed to undeveloped patterns and then very rapidly shifts to the most strategic patterns. For experienced players in the one-second condition, the dicriminability was higher for undeveloped patterns than for developed patterns, whereas the opposite effect was observed in the five-second condition. In contrast, for the novices in both the one- and five-second conditions, the d' were the same for undeveloped and developed patterns. However, for novices, regardless of the position display time, the decision criterion was stricter for developed than for undeveloped patterns, when experienced players' decision criterion was less for undeveloped patterns than for developed patterns in the one-second condition.

GENERAL DISCUSSION

Taken together, the results of the two experiments reported here provide further insight into how novices and experienced players perceive chess positions. They allow us to describe the time course of the exploration process—that is, the processing order of "undeveloped" and "developed" patterns.

The results of the first experiment, which used the flicker paradigm, showed that for experienced players, changes made in developed patterns were detected faster (around 3–4 s) than changes in undeveloped patterns; it was not until later that the experienced players detected changes in undeveloped patterns. For novices, the detection of changes occurred later than for experienced players (between 4 and 10 s), but there was no difference between undeveloped or developed patterns.

The results of the second experiment, which used a recognition task, provided further information about the exploration process performed by experienced players and novices within the first few seconds. After seeing a chess position for only one second, the experienced players recognized the undeveloped patterns well, although they made many false recognitions on undeveloped patterns that had not been presented during the experiment but had been encountered often in the past. In contrast, they did not recognize developed patterns very well at this point. After seeing the position for five seconds, though, the tendency was the opposite: Developed patterns were recognized better and faster than undeveloped patterns.

These findings argue in favour of our main hypothesis concerning the experienced players: initial fast exploration of undeveloped patterns at the periphery of the chessboard, followed rapidly by the encoding of central developed patterns. Thus, the results suggest that during the very first seconds of chess-position exploration, experienced players encode undeveloped patterns globally. Only a few cues from a position would be needed to identify the undeveloped patterns via the activation of perceptual chunks in long-term memory. This global encoding process, which would require little information intake, would appear to take place within a very short time (1 to 2 s), enabling experienced players to quickly shift their attentional focus to patterns with more strategic value. Then an analytical approach would be used to encode the developed patterns. Our results showed in addition that these characteristics of expert perception are present early on. Our experienced players were in fact still acquiring chess expertise (they corresponded, for example, to the "novices" in the Gobet & Simon, 2000, study). It remains to be determined whether the results obtained here can be generalized to players with more expertise (masters and grandmasters).

The findings for the novices were very different. The results of Experiment 1 showed that novices detected changes later than experienced players did. It appears as though the novices explored the different areas of the positions (middle or edges of chessboard) in an erratic fashion, limiting their encoding to a few pieces. The results of Experiment 2 showed that if the position display time was long enough (five seconds), undeveloped-pattern recognition became better than developed-pattern recognition. This result would be due to a feeling of familiarity suggesting that novices have already some chunks in LTM.

A description of expert visual exploration can now be proposed to account for the set of findings obtained in the two experiments presented here. "The difference in achievement between master and non-master rests primarily on the fact that the master, basing himself on an enormous experience, can start his operational thinking at a much more advanced stage" (de Groot, 1965, p. 306). Expert exploration of a domain-specific visual scene may begin with a global, nonexhaustive encoding of the entire scene. With peripheral vision, experts may be able to recognize undeveloped, frequent elements "after a single glance" (Chase & Simon, 1973b, p. 64) and to very quickly activate the perceptual knowledge structures corresponding to those patterns in LTM—that is, perceptual chunks. By combining perceptual chunks with each other, they would obtain more and more information about the category of the scene being processed and could then detect the most informative elements. The allocation of attentional resources summarized by the general heuristic "Don't waste time on anything that's normal" (de Groot & Gobet, 1996, p. 177) seems in fact to be a fundamental characteristic of expert perception and illustrates the "perceptual advantage" of experts over novices hypothesized by Chase and Simon (1973b).

In sum, by relying on the many chunks they have stored in LTM, experts can quickly focus their attention on "strategic perceptual characteristics" (de Groot & Gobet, 1996; Gobet & Simon, 1996a; Jongman, 1968). At this level, expert perception would become analytical: Experts would identify which elements are informative and where they are located in the visual scene, in order to grasp all of the semantic relations they encompass. Thus, at the end of the visual exploration phase, experts would have at their disposal a set of perceptual chunks corresponding to "normal" (undeveloped, fixed) elements, as well as a set of semantic relations between the various information-bearing elements of the visual scene. Our results offer new data relative to how strategic chunks may help trigger the plans that are appropriated to a given position. They detail how strategic knowledge is progressively stored and facilitates the road to mastery.

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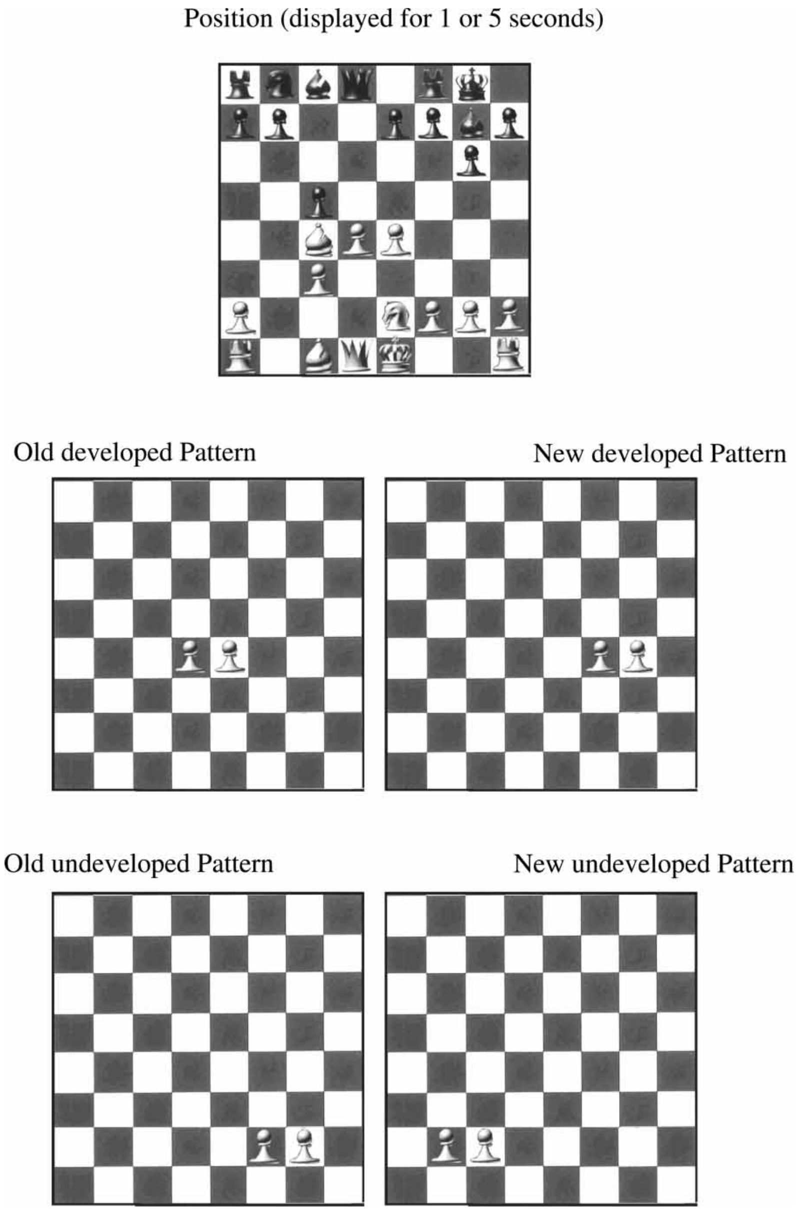
APPENDIX A

Evaluations by three experts (2,000, 2,100, and 2,100 Elo points) and a master (2,400 Elo points) of the immediate strategic rates of the seven chess positions used in Experiments 1 and 2

		Immediate strategic rate			
Reference		*Expert 1 (2,000 Elo)*	*Expert 2 (2,100 Elo)*	*Expert 3 (2,100 Elo)*	*Master (2,400 Elo)*
1	Undeveloped	5	5	3	0
	Developed	3	3	3	4
	Undeveloped	5	5	5	0
	Developed	5	4	5	1
2	Undeveloped	5	3	3	0
	Developed	5	4	4	0
	Undeveloped	0	2	1	0
	Developed	4	3	5	1
3	Undeveloped	0	0	0	0
	Developed	1	4	3	3
	Undeveloped	0	0	0	0
	Developed	5	3	4	3
4	Undeveloped	0	0	0	5
	Developed	3	5	4	0
	Undeveloped	0	3	2	0
	Developed	1	4	4	5
5	Undeveloped	0	0	0	0
	Developed	5	5	5	5
	Undeveloped	0	0	0	0
	Developed	0	1	2	5
6	Undeveloped	0	0	0	0
	Developed	5	5	5	4
	Undeveloped	0	0	0	0
	Developed	5	5	5	3
7	Undeveloped	0	0	0	5
	Developed	3	2	3	3
	Undeveloped	0	0	0	5
	Developed	5	3	5	3

APPENDIX B

Example of a chess position and four small configurations presented in the experimental phase of Experiment 2



APPENDIX C

Hits and false alarms by expertise level (experienced players vs. novices), display time (1 vs. 5 s), and pattern type (undeveloped vs. developed) in Experiment 2

		One second		*Five seconds*	
		Undeveloped	*Developed*	*Undeveloped*	*Developed*
Experienced players	Hits	92.50	31.75	65.85	76.60
	False alarms	67.55	23.35	45.90	28.40
Novices	Hits	56.65	45.75	64.20	40.90
	False alarms	45.05	25.05	40.05	23.55

Note: Hits and false alarms in percentages.