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Dynamic perception in chess

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The present study examines the dynamic aspects of perceptual processes in expert chess players. This topic is approached in terms of the anticipation processes carried out by experienced players during the encoding of chess positions. The aim of the first experiment, which used a short-term comparison task, was to stress the role of anticipation, which allows expert players to focus their attention on the area of the studied position where they expect the likely standard move to occur. The second experiment used a long-term recognition task. The results showed that expert players made many false recognitions on the new positions that could be expected from the positions presented in the preliminary study phase. Taken together, the results of the two experiments highlight the anticipatory component of expert perception.

Since de Groot's (1946, 1965) work, the links between perception and expertise have been demonstrated many times. Because expert knowledge differs from that of novices, experts perceive visual scenes differently if those scenes are from their domain of expertise—that is, they encode them better and faster than novices do. This perceptual advantage has also been demonstrated many times, on a variety of memory tasks and in a wide range of domains, including chess (Chase & Simon, 1973a; de Groot, 1946, 1965), bridge (Charness, 1979; Engle & Bukstel, 1978), the game of go (Reitman, 1976), medical expertise (Norman, Brooks, & Allen, 1989), music (Sloboda, 1976), electronics (Egan & Schwartz, 1979), programming (McKeithen, Reitman, Rueter, & Hirtle, 1981), baseball (Chiesi, Spilich, & Voss, 1979), or street name memorization by taxi drivers (Kalakoski & Saariluoma, 2001). Another characteristic of expert perception is its anticipatory nature. When experts see a visual scene, they are thought to activate possible scenes that might follow the current scene. In the domain we are interested in here—the game of chess—although this feature of expertise is part of most models (Chase & Ericsson, 1982; Chase & Simon, 1973b; de Groot, 1946, 1965; Gobet & Simon, 1996b; Simon & Gilmartin, 1973), it has apparently never been demonstrated experimentally. The present study thus attempts to provide evidence of this dynamic aspect of expert perception.

The first author to have mentioned the dynamic nature of expert perception in chess was de Groot (1946, 1965). By analysing the verbalizations of expert players, de Groot noted that experts seem to automatically activate moves that follow the observed scene. "The chessmaster sees in a few seconds 'what's cooking in a certain position', i.e., which typical playing methods the situation

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on the board demands, enables him to begin his investigation in a highly specific direction" (de Groot, 1965, p. 297). This "automatic" activation is thought to be rooted in the nature of expert knowledge. For de Groot, a chess master perceives a typical position in "large complexes" like a castled position, a pawn structure, or a number of cooperating pieces. Such large complexes allow a chess master to "see" the key elements in a certain position and to anticipate the likely standard move (de Groot, 1946, 1965). De Groot defined a large complex as a unit of perception and significance. Since de Groot's research, every branch of research in chess expertise has taken an interest in the respective roles of perceptual and strategic information (Chase & Simon, 1973a, 1973b; Cooke, Atlas, Lane, & Berger, 1993; Gobet & Simon, 1996a; Goldin, 1978a; McGregor & Howes, 2002).

Chase and Simon (1973a) replicated the main results obtained by de Groot (1946, 1965) and used a precise information-processing language to propose a model of the acquisition of chess expertise: chunk theory (Chase & Simon, 1973b). For these authors, chunks are familiar patterns of pieces commonly found in chess games. In their model, expertise is acquired through the learning of a very large number of chunks indexed by a discrimination network. Such networks enable the rapid categorization of domain-specific patterns and account for the speed with which expert players "see" the key elements of a problem. This theory brings to bear several parameters specific to the information-processing system, including the capacity (7 ± 2 chunks) of short-term memory (STM). Because master players have more chunks stored in long-term memory (LTM), they recognize more and larger patterns on the chessboard and can therefore remember the locations of the pieces better. When participants have to memorize random locations, few patterns are recognizable, and the superiority of expert players virtually disappears (Chase & Simon, 1973a; Gobet & Simon, 1996a). Thus, what emerges from chunk theory is that the skilfulness of chess masters is based on their store of chunks in LTM, and that the critical process involved in memory tests is familiar-pattern recognition. However, in addition to the pieces themselves that make up such chunks—in Chase and Simon's definition of the term—chunks are linked to each other both spatially (e.g., the pieces in the first row on the chessboard) and strategically (e.g., the pawn configuration that protects the castled king, or a chain of attacking pawns protecting each other). If an expert's skill indeed lies essentially in the recognition of familiar patterns, then certain chunks may convey information about the most likely moves. However, the existence of chunks that give access to the strategy of the game is no doubt the least explored aspect of the theory.

In many subsequent studies on expert memory, it has been argued that certain parts of chunk theory are incorrect. First, contrary to classic theories of STM, one study by Charness (1976) showed that expert chess players are relatively insensitive to interfering tasks. This finding suggests that they utilize more than just their working memory to store the patterns they recognize. Second, other studies (Cooke et al., 1993; Frey & Adesman, 1976; Goldin, 1978a, 1978b; Holding, 1989; Holding & Reynolds, 1982; Lane & Robertson, 1979; Saariluoma, 1989) have shown that chunk theory does not sufficiently take semantic aspects into account.

In the light of these inconsistencies, Gobet and Simon (Gobet, 1998; Gobet & Simon, 1996b) proposed template theory, a revised version of Chase and Simon's (1973b) model. This theory retains the idea that the capacity of STM is limited to 7 ± 2 chunks. It also still includes a discrimination network that activates relevant chunks in LTM. Among these chunks, Gobet and Simon (1996b) distinguished not only sets of pieces corresponding to Chase and Simon's chunks, but also new knowledge structures called templates. In chess, templates generally represent a familiar opening after 10 or 15 moves. They have more pieces than do chunks, which in the Chase and Simon model never exceed 4 or 5 men. When a position is recognized, the corresponding chessboard representation in memory contains specific information about the location of a certain number of chessmen (about a dozen), as well as "slots" (usual locations in that particular opening) with default values that can be rapidly updated. Access to these powerful retrieval structures accounts for the large chunks that chess masters are able to recall at different positions in the game (Gobet & Simon, 1996a). Templates are cued by the salient characteristics of the position being processed, and are recognized early and expanded rapidly by slot filling. Slots can contain visual information, such as the location of certain pieces, but they may also contain semantic information like plans and tactical and strategic features (Gobet, 1997), especially information about the most likely moves from encoded positions (Gobet & Simon, 1996b).

Ever since de Groot's work, all models of chess expertise have hypothesized automatic access to information about the dynamics of the game: When facing a typical game situation, experts are thought to activate the best moves to make, right from the very moment they begin encoding the scene. This feature of expertise is what allows them to maintain a high performance level during games where time pressure is great (blitzes, simultaneous games, etc.; see Calderwood, Klein, & Crandall, 1988; Gobet & Simon, 1996c). Although this feature of expert perception is included in most models, it has never been demonstrated experimentally. In the present study, two experiments were conducted to highlight this aspect of expert perception.

The first experiment used a short-term comparison task and various levels of expertise, in order to provide further experimental support for the anticipatory nature of expert perception. This study should allow us to show that visual encoding carried out by expert chess players includes the recognition of familiar patterns and of the semantic relationships between elements in a chess position—that is, dynamic aspects relative to how the game is likely to proceed. By studying excerpts of dynamic scenes (i.e., classic opening positions), expert players should be able to anticipate the likely standard moves (i.e., the successive steps in the strategy to employ for the game in progress). To test this hypothesis, we asked chess players of different expertise levels to perform a chess position comparison task. They had to indicate as quickly as possible whether two positions in a pair were identical or different. The positions showed classic chess openings. The openings were not simple sequences of moves, but expressed "ideas", chess "themes"—that is, each opening was associated with a plan that enabled the player to organize an attack or a configuration that would put the opponent in a weaker position. As such, classic openings correspond to goal-oriented manoeuvres. In the present study, two successive positions in an opening were considered as two "stages" in a dynamic situation. To manipulate the dynamic aspects inherent in these stages, two display order conditions were set up. In one condition, the positions were shown in the normal playing order, and in the other they were shown in the reverse order. In addition, two different types of pairs were designed. In one type, each prototypical opening position was paired with a standard-move position in the game, and in the other type, each opening position was paired with a nonstandard-move position. Anticipation processes should allow expert players to automatically activate the next scene (Chase & Simon, 1973a, 1973b; de Groot, 1946, 1965; Gobet & Simon, 1996b) and thereby focus their attention on the area of the studied position where they expect the likely standard move to occur (de Groot & Gobet, 1996). Accordingly, the condition assumed to be the most favourable for expert players was the one where the game took place in the normal order, and the opening position was immediately followed by the likely standard-move position (Gobet & Jansen, 1994). We expected better or at least faster comparison performance in this condition for expert players, but not for beginners.

The second experiment was conducted to take an in-depth look at the visual encoding of expert players using a long-term recognition task. In this task, expert players and beginners in chess had to study a series of positions (first phase) and then recognize the studied positions among new positions (second phase). The new positions were modified versions of the studied positions, with one piece changed: For half of them, the new positions were one-move-after positions representing the next plausible move, and for the other half, they were one-move-before positions that preceded the old positions. It was hypothesized that for each opening position studied in the first phase, expert players would automatically anticipate a likely standard move. Consequently, in the long-term recognition task we predicted that expert players would falsely recognize more one-move-after positions than one-move-before positions.

EXPERIMENT 1

This experiment tested the hypothesis that chess experts' knowledge is organized around the dynamics of the game and, more specifically, that their perception is anticipatory. Dynamic aspects were integrated by using opening positions as items (again, an opening position was regarded as a dynamic scene), and game dynamics were manipulated by setting up two display order conditions. The participants' task was to quickly and accurately compare pairs of chess game positions ("different" or "identical" pairs). Two types of "different" pairs were generated. In one type, each opening position was paired with a standard-move position in the game; this kind of pair was called a "standard-move" pair. In the other type, each opening position was paired with a nonstandard-move position. For both types of pairs, the positions to be compared were shown in the normal playing order in one display order condition, and in the reverse order in the other (see Figure 1).

If expert players' visual encoding is related to the dynamics of the game, then in studying a classic chess position (i.e., a prototypical opening position), they should rapidly anticipate a standard move from the opening position. This anticipation process should allow them to focus their attention on the area where they expect the standard move to occur. Consequently, for the pairs that were different, we expected expert players' comparisons to be better, or at least faster, when the positions were presented in the normal order than when they were in the reverse order, but only on standard-move pairs (which reflect the normal development of an opening). There should be no display-order effect for beginners, who do not have enough knowledge to facilitate dynamic anticipation. The nonstandard-move pairs served as a control condition so that we could show that the display order had no effect when the two positions did not reproduce the dynamics of the game.

Concerning the identical pairs, we predicted both a higher percentage of correct answers and shorter correct-answer latencies for expert players than for beginners, since the visual encoding of expert players is more efficient than that of weaker players (Chase & Simon, 1973a; de Groot, 1946, 1965; de Groot & Gobet, 1996; Reingold, Charness, Pomplun, & Stampe, 2001).

Method

Participants

A total of 40 chess players participated in the experiment (mean age: 28 years 6 months, *SD* = 6 years 8 months). Of these, 20 were Class C players learning to play chess (mean age: 27 years 4 months, *SD* = 4 years 8 months; mean number of Elo points: 1,528, *SD* = 69.3 points), hereafter called "beginners", and 20 were more experienced players from Class A (mean age: 30 years 4 months, *SD* = 7 years 2 months; mean number of Elo points: 1,903.5, *SD* = 78.4 points), hereafter called "expert players". All participants played regularly in a chess club.

Materials

The positions used were prototypical opening positions. They were taken from a book about chess openings written by J. N. Walker (1975) and published by the French Federation of Chess. This book, frequently used in French chess clubs, describes and comments upon the opening positions needed for proper learning of the game. Note that a postexperimental interview showed that beginners and expert players alike recognized all of the opening positions used in the

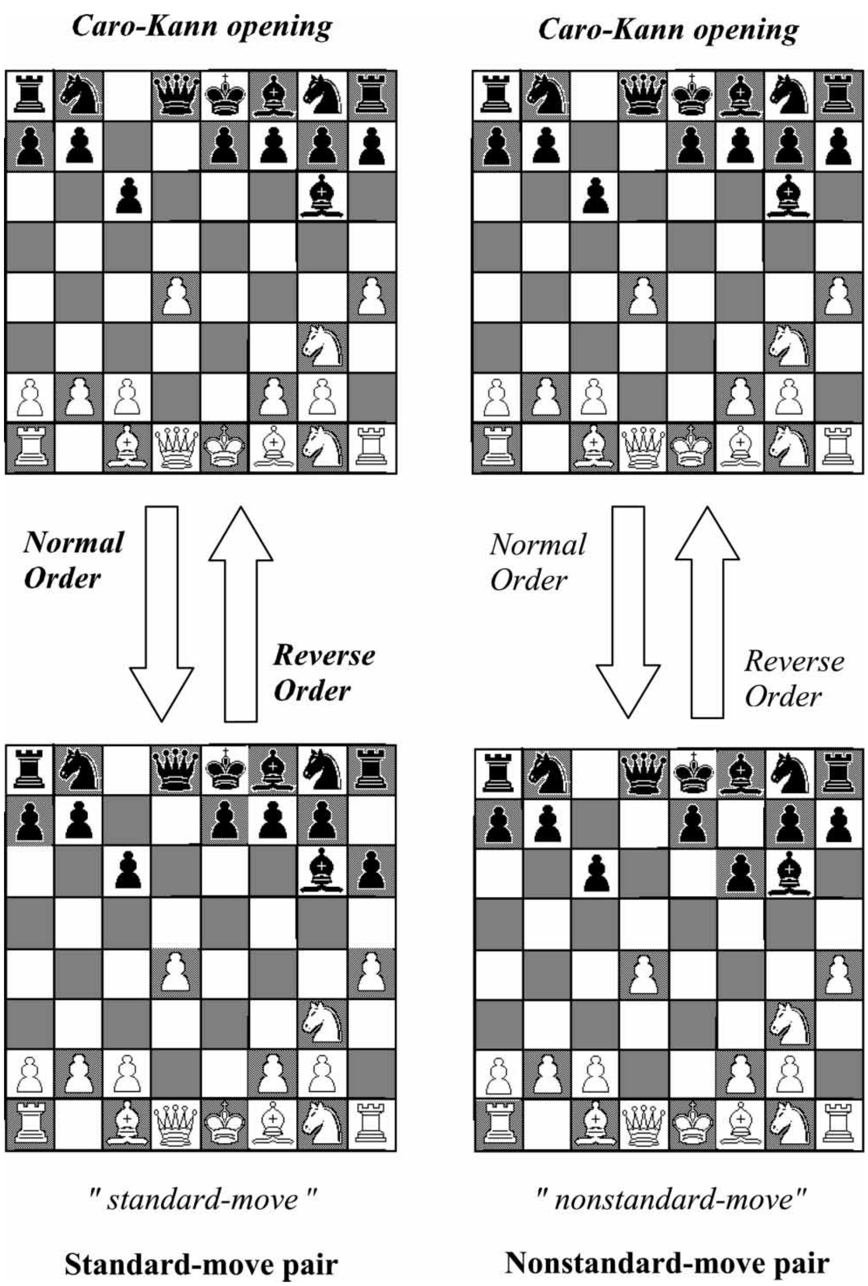

Figure 1. *Standard-move and nonstandard-move pairs.*

experiment, but only expert players said they regularly made use of these openings when they played. The 13 opening positions selected were game positions after an average of 10 moves.

Familiarization phase. The materials for the familiarization phase were generated from an opening called the Nimzo-Indian defence. This opening was not reused during the experimental phase.

Experimental phase. A total of 48 pairs of items (24 test pairs and 24 filler pairs) were constructed from 12 prototypical positions of classic chess openings. The 24 test pairs consisted of 12 "different" pairs and 12 "identical" pairs. For the 12 different pairs, each opening position was paired either with a standard-move position in the game ("standard-move pairs") or with a nonstandard-move position ("nonstandard-move pairs"). In both conditions, the only piece moved was a pawn, and it was moved by one square only. The moved pawn was white in half of the cases and black in the other half. The 12 identical pairs (same position shown twice) consisted of the two modified positions from each of the six opening positions. The 24 filler pairs were also divided into 12 "different" pairs and 12 "identical" pairs. For the different pairs, it was not a pawn that was moved but a rook, a knight, or a bishop. The identical filler pairs were generated in the same way as were the identical test pairs.

Design

The 40 participants were divided into four experimental groups defined by the player's level of expertise and the presentation order. Half of the participants were expert players (Group 1 averaging 1,907 Elo points, $SD = 85.8$ points; Group 2 averaging 1,900 Elo points, $SD = 74.7$ points), and half were beginners (Group 3 averaging 1,534 Elo points, $SD = 64.2$ points; Group 4 averaging 1,522 Elo points, $SD = 77$ points). Group 1 and Group 3 were assigned to the normal-order condition, and Group 2 and Group 4 to the reverse-order condition. In the normal-order condition, the first position presented was an opening position, and the second was either a standard-move position or a nonstandard-move position. In the reverse-order condition, the positions were presented in the opposite order. In all conditions the pairs were presented in a random order that was different for all conditions and for all participants.

Procedure

The experiment was run on a portable Macintosh PowerBook G3 computer. The participants' task was to compare pairs of positions from a chess game, as quickly and as accurately as possible. The two positions in a pair were displayed in succession. The first position, preceded by the message "First Position", remained on the screen for five seconds. Then the message "Second Position" appeared, and a beep announced the display of the second position. The participants had to decide whether the second position was the same as or different from the first by pressing one of two buttons. The second position disappeared when the response was given. All participants underwent a familiarization phase consisting of eight trials, four with different pairs and four with identical pairs. The participants were informed that their response times would not be recorded during this phase.

Results and discussion

Identical pairs versus different pairs

Two analyses of variance (ANOVAs) were conducted on the percentage of correct answers and on correct-answer latencies, with the type of comparison (identical pairs vs. different pairs) as a within-subject factor and the expertise level (expert players vs. beginners) as a between-subjects factor. Table 1 presents the mean percentage of correct answers and the mean correct-answer latency for expert players and beginners, for each type of comparison.

Percentage of correct answers. The results yielded a significant effect of the expertise level, $F(1, 38) = 8.40$, $MSE = 148.564$, $p < .01$. The

Table 1. *Mean percentage of correct answers and mean correct-answer latency*[a] *for expert players and beginners, by type of comparison*

	Identical pairs		*Different pairs*	
	% Correct	*Latency*	*% Correct*	*Latency*
Expert players	88.67	2.98	88.3	2.20
Beginners	83.27	3.70	77.9	2.06

[a]In s.

percentage of correct answers was significantly higher for expert players than for beginners (88.49%, $SD = 11.97$ vs. 80.59%, $SD = 10.87$). The effect of the type of comparison was nonsignificant, $F(1, 38) = 1.75$, $MSE = 94.22$, $p > .1$. The results indicated no significant interaction between the expertise level and the type of comparison, $F(1, 38) = 1.32$, $MSE = 94.22$, $p > .1$.

Correct-answer latency. A cutoff point of three standard deviations above and below the mean for each subject was set to minimize the effect of outliers. Outliers were removed before analysis (less than 5% for each subject in every condition). The results indicated a significant effect of the expertise level, $F(1, 38) = 4.79$, $MSE = 0.347$, $p < .05$. Correct-answer latencies were significantly shorter for expert players than for beginners (2.59 s, $SD = 0.71$ vs. 2.88 s, $SD = 0.51$). A significant effect of the type of comparison was found, $F(1, 38) = 125$, $MSE = 0.234$, $p < .01$. The latencies on identical pairs were significantly longer than those on different pairs (3.34 s, $SD = 0.58$ vs. 2.13 s, $SD = 0.52$). The interaction between the type of comparison and the expertise level was significant, $F(1, 38) = 15.82$, $MSE = 0.234$, $p < .01$. The identical-pair latencies were significantly longer than the different-pair latencies both for expert players, $F(1, 19) = 35.32$, $MSE = 0.343$, $p < .01$ (2.98 s, $SD = 0.66$ vs. 2.20 s, $SD = 0.50$) and for beginners, $F(1, 19) = 121.14$, $MSE = 0.443$, $p < .01$ (3.70 s, $SD = 0.47$ vs. 2.06 s, $SD = 0.55$).

These classic results support the hypothesis of better and faster visual encoding of chess configurations by expert players than by beginners (Chase & Simon, 1973a; de Groot, 1946, 1965; de Groot & Gobet, 1996; Reingold et al., 2001).

Different pairs

Two ANOVAs were conducted on the percentage of correct answers and on the correct-answer latencies for different pairs, with the type of pair (standard-move pair vs. nonstandard-move pair) as a within-subject factor and the expertise level (expert players vs. beginners) and display order (normal order vs. reverse order) as between-subjects factors (see Table 2 for all results). No statistical processing was done on the filler stimuli.

Percentage of correct answers. Table 2 presents the percentage of correct answers by expertise level, display order, and type of pair.

A significant effect of the expertise level was found: The percentage of correct answers was significantly higher for expert players (88.3%, $SD = 12.32$) than for beginners (77.9%, $SD = 16.60$), $F(1, 36) = 7.74$, $MSE = 279.48$, $p < .01$. There was no significant effect of the display order, $F(1, 36) = 1.006$, $MSE = 279.48$, $p > .10$, nor of the type of pair, $F(1, 36) < 1$, $MSE = 173.80$. Only the interaction between the display order and the expertise level was significant, $F(1, 36) = 9.05$, $MSE = 173.80$, $p < .01$ (all other double interactions were nonsignificant, as was the triple interaction Expertise × Order × Position Type). Planned comparisons showed that order had an effect for expert players, $F(1, 18) = 9.02$, $MSE = 249.24$, $p < .05$ (95.8% for the normal order, $SD = 8.50$ vs. 80.8% for the reverse order, $SD = 16.05$), but not for beginners, $F(1, 18) = 1.81$, $MSE = 381.72$, $p > .05$.

Correct-answer latency. Figure 2 presents the correct-answer latency mean (in seconds) for expert players and beginners on standard-move and nonstandard-move pairs in the normal and reverse display order conditions.

Setting a cutoff point of three standard deviations above and below the mean for each subject minimized the effect of outliers. Outliers were

Table 2. *Mean percentage of correct answers for the various kinds of pairs, by level of expertise, display order, and type of pair*

	Standard-move pairs		*Nonstandard-move pairs*	
	Normal order	*Reverse order*	*Normal order*	*Reverse order*
Expert players	93.3	85	98.3	76.7
Beginners	70	78.4	78.3	84.9

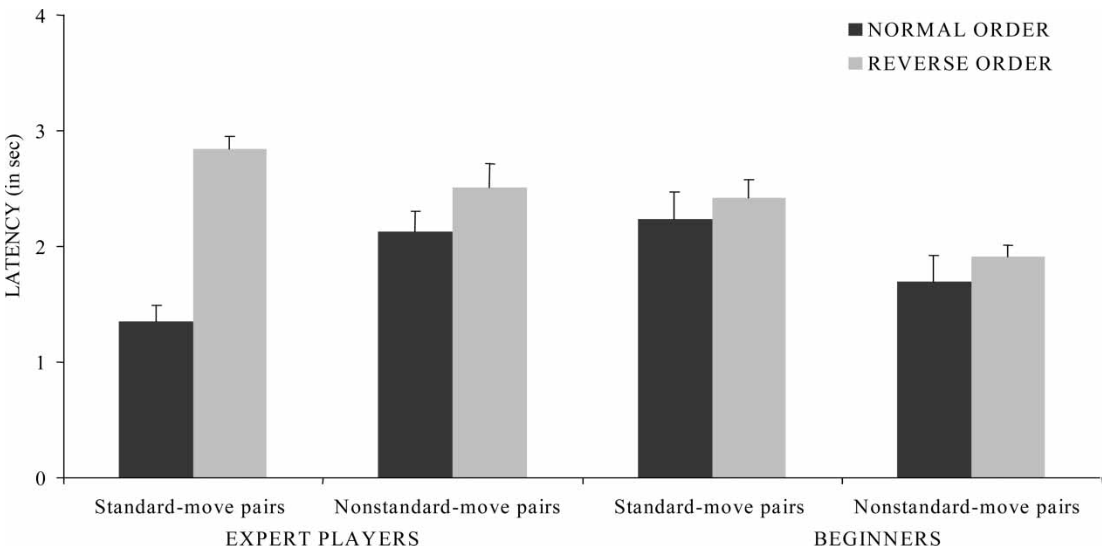

Figure 2. *Mean correct-answer latency (in seconds) for expert players and beginners on the two types of pairs (standard-move vs. nonstandard-move), by position display order (normal order vs. reverse order). Error bars are standard errors.*

removed before analysis (less than 5% for each subject in every condition). On correct-answer latencies, there was no expertise-level effect, $F(1, 36) < 1$, $MSE = 0.47$, nor type-of-pair effect, $F(1, 36) = 3.76$, $MSE = 0.12$, $p > .05$, but there was a significant effect of the display order, $F(1, 36) = 13.45$, $MSE = 0.47$, $p < .001$. The normal-order latencies were significantly shorter than the reverse-order latencies (1.85 s, $SD = 0.44$ vs. 2.42 s, $SD = 0.60$).

The results indicated significant interactions between the expertise level and the type of pair, $F(1, 36) = 21.50$, $MSE = 0.12$, $p < .001$, between the display order and the type of pair, $F(1, 36) = 11.44$, $MSE = 0.12$, $p < .01$, and between the display order and the expertise level, $F(1, 36) = 5.72$, $MSE = 0.12$, $p < .05$. A significant triple interaction was found between display order, level of expertise, and type of pair, $F(1, 36) = 12.28$, $MSE = 0.12$, $p < .01$.

Concerning the interaction between expertise level and type of pair, the results indicated that the latencies on standard-move pairs were significantly longer than those on nonstandard-move pairs for beginners, $F(1, 18) = 22.05$, $MSE = 0.126$, $p < .01$ (2.33 s, $SD = 0.60$ vs. 1.80 s, $SD = 0.53$) but not for experts, $F(1, 18) = 1.68$, $MSE = 0.270$, $p > .05$ (2.10 s, $SD = 0.85$ vs. 2.30 s, $SD = 0.63$). This result may be related to the critical difference between the standard-move and nonstandard-move positions. For nonstandard-move positions, the modifications always concerned a pattern close to the original undeveloped position (rows 1, 2, 7, or 8), whereas this was not always the case with standard-move positions. This finding supports the idea that beginners' knowledge includes familiar chunks in their original undeveloped positions.

Concerning the other interactions, planned comparisons revealed, first, that the normal-order latencies were significantly shorter than the reverse-order latencies for expert players, $F(1, 18) = 20.75$, $MSE = 0.42$, $p < .01$ (1.74 s, $SD = 0.51$ vs. 2.68 s, $SD = 0.51$) but not for beginners, $F(1, 18) < 1$, $MSE = 0.53$ (1.96 s, $SD = 0.38$ vs. 2.16 s, $SD = 0.71$) and, second, that for expert players the normal-order latencies were significantly shorter than the reverse-order latencies on standard-move pairs, $F(1, 18) = 69.01$, *MSE* = 0.16, $p < .01$ (1.35 s, *SD* = 0.34 vs. 2.84 s, *SD* = 0.45) but not on nonstandard-move pairs, $F(1, 18) = 1.90$, *MSE* = 0.38, $p > .05$ (2.12 s, *SD* = 0.67 vs. 2.51 s, *SD* = 0.56).

These results provide insight into the nature of expert players' perception. The use of a dynamic situation involving stages of the game (excerpts of openings) allowed us to show that experts' visual encoding includes the relationships between the elements of successive stages, whereas beginners' encoding does not. The main result obtained here concerns the correct-answer latencies. The expert players—but not the beginners—had the shortest response times when they were comparing standard pairs in the normal order. Thus, the recognition of a prototypical opening position seems to activate additional information about the dynamics of the game in expert players' memory. With this additional information, expert players can focus their attention on the area where the modification of the second position will occur. Did anticipation processes lead to facilitation in the normal-order condition, and/or did they slow down the comparison process in the reverse-order condition? We cannot draw a firm conclusion yet. Note simply that in the reverse-order condition, the response time was marginally longer for standard than for nonstandard pairs, $F(1, 9) = 3.83$, *MSE* = 0.146, $p = .08$, which argues in favour of a slower comparison process when experts had to compare standard positions to prototypical positions than when they had to compare nonstandard positions to prototypical positions. On the other hand, in the normal-order condition, response times were shorter for standard-move pairs than for nonstandard pairs, $F(1, 9) = 28.59$, *MSE* = 0.100, $p < .01$, which suggests facilitation due to the normal order.

Experiment 2 used a long-term recognition task to provide additional support for the hypothesis that expert visual encoding includes information about the relationships between elements in successive chess positions. It was designed to show that when studying a prototypical opening position, expert players anticipate the likely standard move in the normal development of the game. However, in this long-term recognition task, the expert players' anticipation of that move would not act in their favour.

EXPERIMENT 2

It was hypothesized that the visual encoding carried out by expert chess players is organized around the dynamics of the game and integrates strategic information that allows them to anticipate a likely standard move. To test this hypothesis, we applied a classic experimental technique often used in the field of perception to study the mental representation of movement (e.g., Didierjean & Marmèche, 2005; Freyd, 1983, 1987; Freyd & Finke, 1984; Vinson & Reed, 2002; for a review, see Intraub, 2002). In these studies, frozen action photographs taken from a single movement (e.g., a person jumping off a wall or an object falling down) were presented in the first experimental phase. In the second phase, participants had to perform a recognition task. The results indicated an asymmetry in the responses: It was more difficult to reject fillers that were farther along the implied path of movement (the same person or object a little farther down) than the reverse (the same person or object a little higher up). More false recognitions were observed in the normal progression of the movement than in the reverse order.

In Experiment 2, we used a recognition test with chess positions as items. There were 10 classic opening positions ($O_1, \ldots O_{10}$). For each opening position, there was one position that corresponded to the next step after the opening position in the normal development of the game—that is, after a standard move ($O_1^{+1}, \ldots O_{10}^{+1}$). In a preliminary study, five opening positions (e.g., $O_1, \ldots O_5$) and five positions after standard moves from other opening positions (e.g., $O_6^{+1}, \ldots O_{10}^{+1}$) were presented to expert players and beginners. On the recognition test, all positions from the study phase (old items) were presented, mixed with new positions. Among the new positions, some depicted the positions after standard moves of already-presented opening positions ($O_1^{+1}, \ldots O_5^{+1}$) or previous positions of old positions ($O_6, \ldots O_{10}$). The participants' task for each item was to state whether they thought that they had already seen that item during the study phase. Note here that we did not use any nonstandard-move positions because the main goal of this experiment was to confirm the results obtained in Experiment 1 about standard-move positions. We were worried that an interference effect might occur if we included nonstandard-move positions (participants would have to study and recognize too many positions: 15 positions, each containing 20 pieces).

If the perception of expert chess players is anticipatory, then they should anticipate the standard-move positions corresponding to the opening positions of the study phase. When faced with a to-be-encoded scene, anticipation processes should trigger the automatic building of an "anticipatory" memory trace corresponding to the position after the standard move (Intraub, 2002). Consequently, we expected expert players, but not beginners, to be inclined to falsely recognize new items as old items when the new positions were positions after standard moves from previously seen opening positions (presented during the study phase). Thus, we predicted a higher false-alarm rate for expert players than for beginners on new items that were positions that came after standard moves from old opening positions.

Method

Participants

A total of 60 chess players (different from those of Experiment 1) participated in the experiment (mean age: 29 years 3 months, *SD* = 11 years 8 months). Of these, 30 were beginners from Class C (mean age: 29 years 8 months, *SD* = 11 years 11 months) learning to play chess (mean number of Elo points: 1,515, *SD* = 75 points), and 30 were expert players from Class A (mean age: 28 years 10 months, *SD* = 11 years 6 months) with more experience (mean: 1,866 Elo points, *SD* = 56 points). All participants played regularly in a chess club.

Materials

A total of 20 chess positions were used: 10 chess openings ($O_1, \ldots O_{10}$) after about 10 moves, and 10 positions that followed those opening positions (one move deeper) in the normal progression of the game ($O_1^{+1}, \ldots O_{10}^{+1}$). Note that a postexperimental interview showed that both the beginners and the expert players recognized all of the opening positions used in the experiment, but only expert players said they regularly made use of them when they played. The openings in Experiment 2 were drawn from the materials of Experiment 1.

Design

Participants were divided into four equal groups (expert players: Group 1 averaging 1,867 Elo points, *SD* = 53 points; Group 2 averaging 1,865 Elo points, *SD* = 61 points; Group 3 averaging 1,514 Elo points, *SD* = 79 points; Group 4 averaging 1,516 Elo points, *SD* = 73 points).

Procedure

The experiment was run on a portable Macintosh PowerBook G3 computer. A recognition task was used. The experiment was carried out in two phases.

Phase 1: Study phase. Participants studied 10 chess positions displayed in succession. Each position remained on the screen for 5 s, and the time between two positions was 3 s. The 40 participants were divided into four groups. For Group 1 and Group 3, the 10 positions presented in the study phase were 5 classic chess opening positions ($O_1, \ldots O_5$) and 5 positions after a standard move from other classic opening positions ($O_6^{+1}, \ldots O_{10}^{+1}$). Groups 2 and 4 were shown the 5 positions after a standard move from the opening positions presented to Groups 1 and 3 ($O_1^{+1}, \ldots O_5^{+1}$) and the 5 opening positions preceding the positions presented to those groups ($O_6, \ldots O_{10}$).

Phase 2: Recognition test. For all participants, the entire set of 20 positions was presented in succession: 10 old positions (those previously seen in the study phase) and 10 new positions. Participants were instructed to press a button for positions that they thought they had "already seen" in the study phase and another button for positions that they thought they had "not seen" in the study phase. The stimulus disappeared when the response was given. The positions were displayed in a random order that was different for each participant.

Results and discussion

An ANOVA was conducted on the percentage of "already seen" responses, hereafter called "positive" answers (hits and false alarms), with item newness (old vs. new) and type of item (opening position vs. standard-move position) as within-subject factors, and level of expertise (expert players vs. beginners) and group (Groups 1 and 3 vs. Groups 2 and 4) as between-subjects factors. Figure 3 shows the percentage of positive answers for expert players and beginners, by type and newness of items.

The results indicated no significant effect of group, $F(1, 56) = 1.42$, $MSE = 300$, $p > .05$, and no significant interaction between group and expertise, $F(1, 56) < 1$, $MSE = 300$, between group and item newness, $F(1, 56) < 1$, $MSE = 557.14$, or between group and type of item, $F(1, 56) = 1.87$, $MSE = 288.57$, $p > .05$. Thus, the results for Groups 1 and 2 and for Groups 3 and 4, were combined.

Hits

The results indicated a significant effect of level of expertise, $F(1, 58) = 22.96$, $MSE = 392.64$, $p < .001$. The hit rate was significantly higher for expert players (73.33%, $SD = 18.43$) than for beginners (56%, $SD = 16.44$). The results yielded a significant effect of type of item, $F(1, 58) = 40.01$, $MSE = 392.64$, $p < .001$, and a significant interaction between type of item and level of expertise, $F(1, 58) = 8.52$, $MSE = 392.64$, $p < .01$. The hit rate was higher for opening positions than for standard-move positions, both for beginners (68.67%, $SD = 17.95$ vs. 43.33%, $SD = 14.93$), $F(1, 29) = 43.80$, $MSE = 219.77$, $p < .001$, and for expert players (78%, $SD = 16.06$ vs. 68.67%, $SD = 20.80$), $F(1, 29) = 5.67$, $MSE = 230.80$,

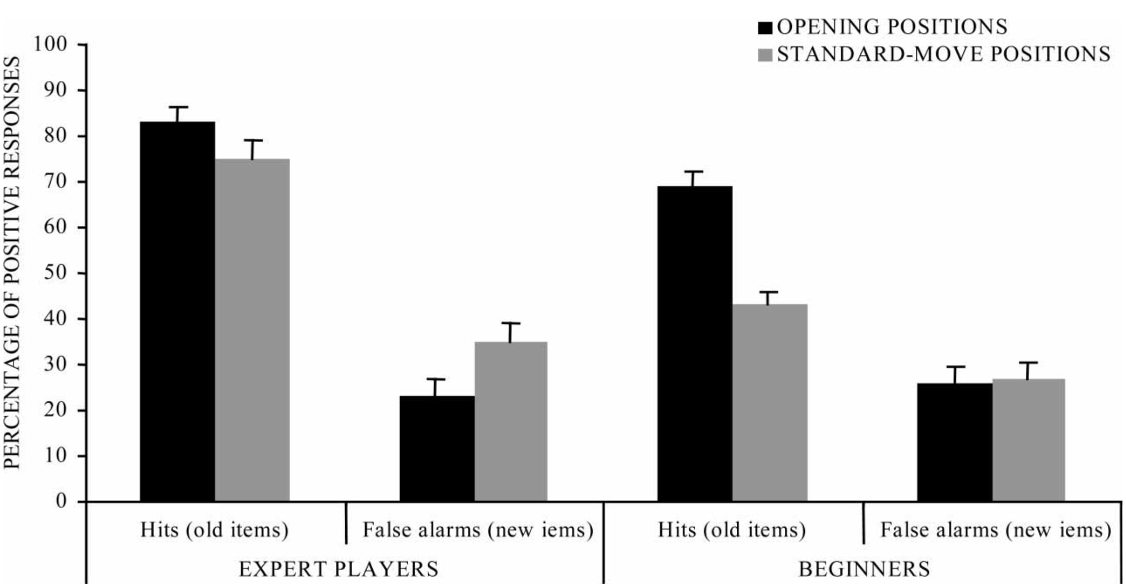

Figure 3. *Percentage of positive responses (hits and false alarms), for expert players and beginners, by type of item (opening positions vs. standard-moves position). Error bars are standard errors.*

$p < .05$. These results may be due to the fact that both experts and beginners were familiar with the prototypical opening positions, but the experts were better able to take the progression of the game into account.

False alarms

Concerning the new items, the results indicated significant effects of expertise level, $F(1, 58) = 7.66$, $MSE = 445.75$, $p < .01$, and type of item, $F(1, 58) = 19.84$, $MSE = 445.75$, $p < .001$, and a significant interaction between expertise level and type of item, $F(1, 58) = 18.08$, $MSE = 445.75$, $p < .001$. The difference between opening positions and standard-move positions was significant for expert players (22.67%, $SD = 17.21$ vs. 51.33%, $SD = 22.70$), $F(1, 29) = 31.16$, $MSE = 258.42$, $p < .001$, but not for beginners (26.0%, $SD = 19.76$ vs. 26.67%, $SD = 18.45$), $F(1, 29) < 1$, $MSE = 244.21$.

These results support the hypothesis that only expert players encode chess positions by integrating standard moves. On the recognition task, the experts had a tendency to confuse new positions with opening positions seen in the study phase whenever they were consistent with their expectations (i.e., standard-move positions corresponding to opening positions presented in the study phase). Such confusions were less frequent for new opening positions that corresponded to previous states derived from the standard-move positions of the first phase. As in Experiment 1, the findings of Experiment 2 point out the dynamic facet of the encoding process performed by expert chess players, especially for moves that can be anticipated from the current game position.

GENERAL DISCUSSION

The aim of the present study was to demonstrate a characteristic of expert perception: its anticipatory nature. The use of situations involving stages of the game (excerpts of chess openings) allowed us to show that expert knowledge includes relationships between elements in successive stages of the game. By manipulating the display order in a short-term comparison task in such a way that the positions either followed or did not follow the normal progression of the game (normal vs. reverse order), we were able to test these dynamic aspects. The main finding of Experiment 1 was that, in the condition where the change was on a standard pair, the presentation of that pair in the normal playing order speeded up the discovery of the change by expert players. The data from Experiment 2 using a long-term recognition task supported the hypothesis that expert players perform a dynamic kind of visual encoding of the positions in a game. It seems that, with expertise, the role of anticipatory perception becomes more and more important. Expert players obtained a high false-alarm rate for items that were likely standard moves from an old position, as if they had anticipated and stored the probable progression of the play in long-term memory.

All of these results validate our predictions about the anticipation processes of expert players, in the comparison task as well as in the recognition task. During the visual exploration of a typical chess position, expert players are able to recognize familiar patterns and rapidly activate the corresponding knowledge structures in LTM. These knowledge structures can convey information about the strategy of the game (e.g., a standard move and the area of the board where that standard move will occur), whether they are called "large complexes" (de Groot, 1946, 1965), "chunks" (Chase & Simon, 1973a, 1973b), or "templates" (Gobet & Simon, 1996b). This characteristic of expert perception is in fact integrated into most models, but until now it has not been tested experimentally. For instance, in Gobet and Simon's (1996b) theory, activated knowledge structures have slots that may include potential moves to make. In this theory, when a position is recognized, expert players may have at their disposal the name of the depicted opening, the location of about a dozen characteristic pieces, and the presumed moves to make at that stage of the game. Our findings provide experimental support for this last point: Both the data obtained for the comparison task in the normal-order condition and the high false-alarm rate on the recognition task show that the information activated during position exploration included likely moves.

The present results point out that information about the dynamics of the game is part of expert knowledge structures and expert perception. Visual exploration by expert players seems to be guided by the presence of familiar patterns (chunks and/or templates) that enable the rapid activation of additional information about the game strategy and allow expert chess players to anticipate the next move and to focus their attention on the area where the next move is likely to occur. In particular, such knowledge structures appear to be organized in terms of stages, in such a way that expert knowledge is structured by goal-oriented processes (e.g., anticipation, inferences, plan of attack, etc.). Expert perception appears here to be tied to visual information (recognition of familiar patterns) as well as to strategic information (e.g., standard moves to make) drawn from the stimuli being processed. Accordingly, research on the nature of expert perception should henceforth strive to devise models in which perceptual processes are directly associated with the activation of strategic information.

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