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Understanding Our Understanding of Strategic Scenarios: What Role Do Chunks Play?

Alexandre Linhares[a,b], Paulo Brum[a]

[a]*EBAPE/FGV, Rio de Janeiro, Brazil*
[b]*Brazilian Chapter, The Club of Rome*

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Abstract

There is a crucial debate concerning the nature of chess chunks: One current possibility states that chunks are built by encoding particular combinations of pieces-on-squares (POSs), and that chunks are formed mostly by "close" pieces (in a "Euclidean" sense). A complementary hypothesis is that chunks are encoded by abstract, semantic information. This article extends recent experiments and shows that chess players are able to perceive strong similarity between very different positions if the pieces retain the same abstract roles in both of them. This casts doubt on the idea that POS information is the key information encoded in chess chunks, and this article proposes, instead, that the key encoding involves the abstract roles that pieces (and sets of pieces) play—a theoretical standpoint in line with the research program in semantics that places analogy at the core of cognition.

Keywords: Representation; Memory; Decision Making; Reasoning; Pattern recognition; Perception; Human experimentation

1. Introduction

Most people are impressed when first studying the results of the recall experiments conducted by de Groot and later by Simon and colleagues, which showed that chess masters are able to reconstruct meaningful positions after rapid glances but cannot reconstruct with the same ease a random scrambling of the pieces found in a position (a number of subsequent simulations reproduce the data with remarkable accuracy; see, for instance, Chase & Simon, 1973a, 1973b; de Groot, 1965; de Groot & Gobet, 1996; Gobet & Simon, 1996a, 1996b, 1996c; Gobet & Simon, 1998a, 1998b; Gobet & Simon, 2000; Lories, 1984, 1987; Simon & Chase, 1973). What initially might impress one may be the unspoken assumption that "a chess position is a chess position is a chess position." But, of course, that is false: Real positions

Correspondence should be addressed to Alexandre Linhares, EBAPE/FGV, Praia de Botafogo 190/509, Rio de Janeiro 22250-900, Brazil. E-mail: linhares@clubofrome.org.br

carry deep meaning; random ones do not. This fact has led to the theoretical position that masters accumulate a number of chunks, which are rapidly perceived in meaningful positions and rarely found in random ones.

The nature of these chunks constitutes a fundamental research question. Chunks might be built by encoding particular combinations of pieces-on-squares (POSs), as classical chunking theory states, in which "close" pieces (in a "Euclidean" sense), the theory states, form chunks. A complementary possibility is that chunks encode abstract, semantic information (e.g., Chabris & Hearst, 2003; McGregor & Howes, 2002). In this article we extend recent experiments and show that chess players are able to perceive strong similarity between two positions if the pieces retain the same abstract roles in both positions. To study this problem, we have a basic observation, a fundamental question, and a thesis.

1.1. Observation: The flexibility of perception

In the game of chess there are similar strategic situations in which the numbers of pieces vary, the sets of pieces vary, the types of pieces vary, the positions of pieces vary, and the underlying search trees vary in depth and in breadth.

Different, but similar: Any student of the game will have seen similar strategic situations involving positions in which these types of variations occur. Sometimes chess masters will mention having seen "the same game" (or position) in the past, but in reality that "same" position actually varied in a number of characteristics. Fig. 1 offers an example from a study book for chess players. How can a position with all the pieces on the board be strategically similar to a position with a mere five pieces? How can positions with radically different search trees be strategically similar? How can positions in which there are few (or no) piece types found in common—kings exempted—be strategically similar? How can positions in which pieces appear in radically different areas be strategically similar? Consider, for instance,

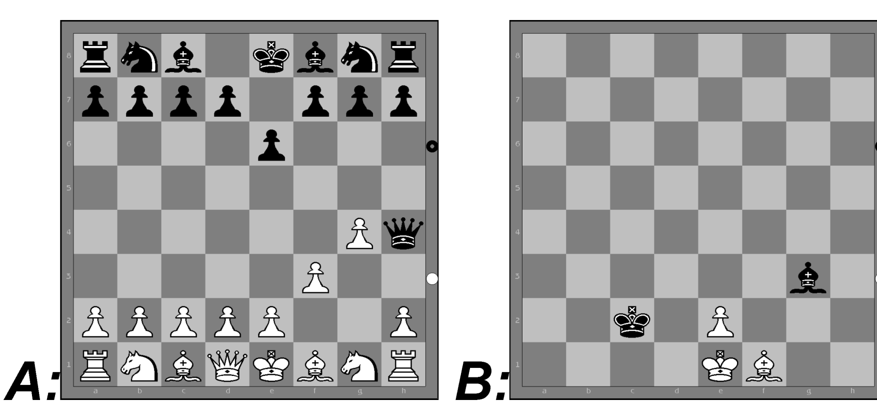

Fig. 1. The fastest possible mate and its "most economical" representation, as given by Ban (1997, p. 12). *Note:* Because these positions differ in number of pieces, position of pieces, and the underlying search tree (from the point of view of the previous ply), how can they be similar to each other?

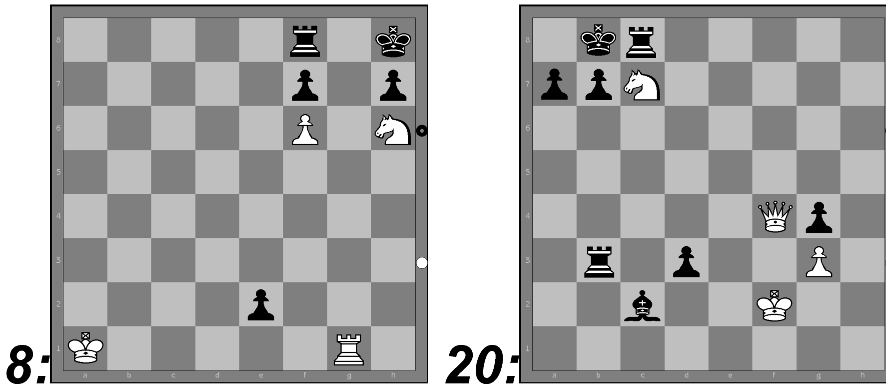

Fig. 2. Positions 8 and 20 used in the experiment (see section 3). *Note:* All positions in the article are white to move. For readers unfamiliar with chess, the solutions are as follows: In position 8, a variant of a position taken from Charness, Reingold, Pomplun, and Stampe (2001), white moves rook to g8 check, black rook captures white rook, white knight captures black pawn at f7, checkmate. In position 20, white moves knight to a6 check (by knight and by queen), black king escapes to a8, white moves queen to b8 check, black rook captures white queen, white knight returns to c7, checkmate. These variations of "Philidor's mate" display high strategic similarity and no similarity at a surface appearance level.

positions 8 and 20 in Fig. 2: These positions display (a) different numbers of pieces, (b) different types of pieces, (c) different tree depth, (d) different tree breadth, (e) different locations of pieces, and (f) different distances between pieces. In all of these aspects, there is hardly any resemblance between positions 8 and 20. However, when we *understand* these positions and see the checkmate, a remarkable similarity *at a strategic-vision level* emerges. What aspect of chess perception structures our strategic vision of a position? This *flexibility of high-level perception* insight leads naturally to the following question.

1.2. Question: The structure of strategic vision

If so many characteristics between different positions can vary, with positions retaining a high degree of strategic similarity, then what underlying aspect of these positions gives rise to the perception of strategic similarity?

We believe that a fruitful approach to this question is to study the perception of similarity of chess positions at a strategic vision level. We propose that underlying the strategic vision of advanced chess players is a process of *perception of abstract roles* played by pieces in the position (i.e., when players perceive a piece or group of pieces (or even empty squares) playing an abstract role in a particular position, a chunk is created in short-term memory). We conduct an experiment to probe whether experts exhibit similar "strategic vision" when similar abstract roles are found in distinct positions. The results show that this is the case, even when the positions seem completely different in all surface features.

For example, chess experts reported that position 6 (see the appendix for all remaining positions referred to) with the white king in a number of different squares would be perceived as "the *exact same* position"—although it is not, in the strict, particular piece-on-particular square sense used by Simon and Gilmartin (1973). Moreover, experts have reported that positions 6 and 10 feel "very similar" *within the group of* 20 used in our experiment. Because positions 6 and 10 differ in the number of pieces, location of pieces, types of pieces present, distance between pieces, tree search depth and breadth, how could these radically distinct positions be perceived as "very similar?" The thesis put forth here is that experts perceive abstract roles played by pieces, and in both positions the passed pawns and the white kings threaten black in cooperation—hence, the abstract roles of the black kings are to defend the pawn from promoting and to defend its pawn structure from the white king. Abstract roles, we propose, are the crucial structures that lead to viewing extremely distinct positions as similar on a "strategic vision level."

Perception, however, is usually taken to be fast, with classical studies having been carried out in tasks taking mere seconds, whereas our procedure requires participants to examine positions for longer than a few seconds. Therefore, it is worthwhile to expand on our use of the word *perception* and its relation to *reasoning* in our view. We see reasoning as "evolving perception" or, more specifically, as an evolving process in which emerging representations face a struggle between a number of hypotheses (brought by top-down active concepts) and the changing, incoming, stimuli (Linhares, 2005). Whereas one might see chess as having "no incoming stimuli" other than the static chess pieces, we propose that a "hypothesis" such as "is there any way to defend the queen while maintaining pressure on that bishop?" may trigger a search process specifically bound to these two pieces and to other pieces that might be seen as playing important roles over the queen or bishop. The result of such a hypothesis-induced process might be a "yes there is" response, for example, or it might be the perception that some other piece is actually playing a previously unforeseen role concerning either the queen or the bishop (or both, or perhaps yet another important piece). In either case such "new" information may be considered incoming stimulus, as it will influence the evolving representation of the situation at hand, and potentially place additional constraints on the plausible actions. The evolving representation primes experts toward high-quality moves (Klein, 1998). It is in this broader sense of "evolving perception" that we use the term *perception*.

A second debate confronting research on chess cognition concerns the question of what is most crucial, thinking-ahead or pattern recognition? Both processes are obviously used by chess players, but because they are usually dealt with as utterly separate, they are topics of a heated controversy in current literature. For instance, Chabris and Hearst (2003, p. 637) argued that because both processes seem important, the controversy between looking ahead and pattern recognition appears "currently unresolvable and perhaps fruitless." We view the process of thinking ahead more as a restraint from the initial impulse primed by the evolved perception (Frederick, 2005) than as a combinatorial tree search. Perception primes some courses of action in detriment of most others; and thinking ahead may perhaps be best seen as restraint from such initially primed course of action. The same *restraint view* of choice has been put forth, in different contexts, by Kahneman (2003), Frederick (2005), and Schelling (2005). Moreover, Klein (1998) found evidence that, under high stakes situations, firefighters, jet pilots, and nurses, among others, would, after recognizing subtle cues of a situation, be primed to act in a certain way and use a simulation heuristic to appreciate the quality of such first response. If this mental simulation brought forth any perceived problem, another course of action would be subsequently primed. It is perhaps possible that the choice generating process does not have a large number of alternatives at once in one's mind but, rather, these alternatives might be considered and discarded in a sequence. Such process would stop when a simulated course of action does not present large obstacles to implementation and a choice is made. In the chess domain, a technique typically employed by players is to, quite simply, "sit on your hands" and resist the first urge to move. We have argued previously that perception involves subtle looking-ahead processes such as perceiving potential piece trajectories, potential threats, and potential interceptions of such trajectories (Linhares, 2005). If this is correct than it is meaningless to discuss processes of perception and "looking ahead" as if they were occurring separately. This view is supported in part by the McGregor and Howes (2002) study, which found out that "expert players' recognition for a piece within a position was primed more by a piece related by attack or defense than by a piece merely proximal" (p. 707).

1.3. Thesis (after Linhares, 2005)

Human experts access chunks by the perception of abstract roles. Chunks are created when a set of abstract roles are perceived to be played by the relevant piece, groups of pieces, or squares. These abstract roles emerge from subtly perceived pressures in many levels such as pieces; key squares; piece mobilities; and attack, defense, and distance relations. Chunks are composed of sets of abstract roles, and their perception leads to a strategic vision of a position.

Consider position 6. After some seconds, we have found that expert players Fédération Internationale des Échecs [FIDE] (ranking around 1,900 points) rapidly recognize that (a) the pawn chains block each other and divide the board, and the only "safe passage" lies on square a2; (b) the white bishop is "held captive" by the pawn chains; (c) the white king is ready to strike, by moving to the other side of the board; (d) the pawn at f5 remains waiting for the right moment to run for the promotion to queen; and (e) the black king is burned out by having to defend from both the pawn upgrade and the upcoming attack from the white king. White will thus promote at least one of its pawns, and rapidly reach checkmate. We propose experts perceive the *abstract roles*, the *intrinsic functions,* played by those pieces at a *global* level.

What is incredibly remarkable is that after such perception, humans do not seem to consider, for instance, the premature move of the white pawn at F5 (or *any* bishop move). After perceiving these simple concepts—or explaining them to those with basic training on the rules of chess—humans can visualize the strategy employed. On the other hand, classical computer-chess programs may routinely consider possibilities such as moving the bishop, which (although still helped by pruning techniques) lead them to explore the combinatorial space in its vastness and to face the horizon effect (examples are discussed in Linhares, 2005, 2006). A key first question we deal with is: Why do humans rapidly disregard irrelevant moves such as those mentioned? How do masters have such acute move-selecting mechanisms? How do humans "prune" the search tree? The essence of our solution is, in short, that humans are able to “conceive and visualize a strategy,” stemming from an acquired ability to quickly access abstract roles. Pieces not perceived to play relevant abstract roles simply are disregarded for the next moves. It is possible that perception of particular combinations of abstract roles may prime experts toward promising moves while inhibiting irrelevant possibilities. Because, in another situation, the same abstract role may be played by a different piece, or may appear in different regions of the board, such an “abstract-role primed movement” hypothesis could account for the incredible extent of expert players’ search selectivity. One acquires a number of combinations of fluid abstract roles (Hofstadter & FARG, 1995), and these could account for a huge number of possibilities afforded by the chess game.

But what should this mean in information-processing terms? We know from the studies of Binet (1894/1981) and others (Chabris & Hearst, 2003) that humans do not visualize the board as “pictorial photographic representations.” So, what exactly constitutes this power of visualization? A contribution of this article is to argue that perception of abstract roles accounts for the psychologically plausible “higher level processes and representational techniques” (as put by Chabris & Hearst, 2003) to model position representation and move selection. The following section presents our experimental findings.

2. An experiment on similarity in strategic vision

Because our experiments tests the semantics involved in chess chunks, we briefly comment analogous experiments on semantics and perception. Sachs (1967), for instance, presented participants with an original paragraph and subsequently asked them to point out whether some particular phrases were present on the original paragraph. Participants easily perceived that, if meaning departed from the original, the phrase could not have been in the originally presented text. However, participants would point out as “the correct sentence” a phrase that shared words and meaning with the original text, but was not in it. Participants were able to retain the essence of the message, but could not retain the specific wording used. The key point we would like to stress is that memory is more prone to find semantic similarity than surface similarity.

These results resonate with the influential study of Chi, Feltovich, and Glaser (1981), which showed that in physics, novices paid excessive attention to surface features of a problem, whereas experts quickly were able to point out the basic physics principle underlying each problem. Novice physics students would tend to classify these types of problems using their surface similarity, with classes such as “always a block of some mass hanging down,” “velocity problems,” “rotation,” “inclined plane,” and so on. On the other hand, experts physicists would tend to classify the problems by giving the underlying physics principles that should be applied to them, regardless of their surface structure. Classifications by experts would thus consist of “Newton’s third law,” “conservation of energy,” “conservation of linear momentum,” and so on. Similar findings have appeared in domains ranging from scientific knowledge to taxi drivers (Chi, 1993). Here again, semantic aspects seem to take precedence in accessing long-term memory: Students still have not acquired the required fundamentals of physics that rapidly lead one to the essence of a particular problem.

2.1. Method

Our experiment is in many ways analogous to this last one: A diverse set of chess players was selected during a period of 6 months during chess club gatherings or tournaments in Rio de Janeiro. Participants were asked to pair positions with a similar *essence,* even if specific piece arrangements were completely different. The reasoning behind our experiment is straightforward: If strategic vision is determined by the perception of abstract roles, then two very distinct positions that have pieces displaying *similar roles* should be perceived as similar at the strategic vision level.

2.2. Participants

The experiment was realized in chess clubs or tournaments organized by the Chess Federation of Rio de Janeiro (FEXERJ). Forty-three chess players, with varying degrees of chess skill and experience, participated. However, results from 7 participants had to be discarded due to errors or discrepancies in following the procedure (4 participants felt burned out after playing a game; a 5th asked for aspirins during the experiment; 2 others, after properly introduced to the task, attempted to cluster positions instead of pairing them). The 36 participants represent a sampling of 4.5% of all players associated with FEXERJ. Participants were divided into two groups according to their ELO rating (ELO, 1978) obtained in the federation's tournaments. One group consisted of novices to chess, whereas the other group's ELO ratings started at 1,600 points, averaging 1,942 points ($SD = 168$). Although this group mostly consisted of Class B and Class A players, some of them held a master level (in FIDE ratings). This group was composed of 22 players overall. The novice (control) group was composed of 14 players with maximum FEXERJ ratings of 1,599, averaging 1,299 points ($SD = 206$). Three players of this control group of participants were still unrated.

2.3. Materials

In our experimental setting, 20 chess positions were carefully designed in which the key abstract roles played by pieces could also be found in another, usually very distinct, position—and, therefore, the theory predicted 10 expected pairings. The abstract roles used are found in Table 1. There were 10 "control positions" in the set, which were very similar in specific POS pairings (with a single pawn included or displaced to another square). All positions were white to move. The positions were easy to solve, with perhaps the exception of position 13. The main idea behind having easy positions is that (a) it enables cognitive scientists unfamiliar with chess to grasp them without difficulty, (b) a comparison between experts and novices could provide insightful results, and finally (c) by studying the errors that novices make, some fundamental points about the learning process might emerge.

These control pairs of positions were specifically devised to check whether players in the different groups would perceive distinctions at a strategic level between two positions that seemed similar on a surface level. As was mentioned above, these positions had at most one piece moved to another square, or a pawn inserted, which did not alter the POS structure significantly, but could drastically alter the strategic situation. Because these pairs do not alter

Table 1
Abstract roles used in designing the pairs of positions

Predicted pairings	Abstract roles
1–7	White moves a piece to a protected square and checkmates
2–4	White moves a piece to a square guarded by black and holds a discovered checkmate
3–16	Pawn structures block passage; kings are unable to strike
5–9	White has a piece that can simultaneously attack the black king and other strong piece(s) in a move (absolute fork), leading to significant material gain
6–10	White king and passed pawn cooperate in threatening to promote; black king must defend from both attacks, and is overwhelmed by the task
8–20	Black king has restricted mobility (unable to move), white can, by sacrificing, sustain that situation and has a knight in close distance
11–19	White has a pawn chain with a passed pawn; white's king is able to make Black's king retreat from protecting it
12–13	The pawn structures are perceived to block each other
14–17	Pawn chains unmovable; bishops unable to attack
15–18	Pawn chains unmovable; white bishop capable of attack, black bishop unable to attack

the POS structure of the positions significantly, according to traditional theories, these models should retrieve from long-term memory a number of similar chunks (which, in other words, means that the positions should seem similar according to these theories). We refer the reader to the appendix for the full set of positions and the corresponding commentary.

2.4. Procedure

The positions were permuted in random order and numbered 1 to 20 using that order. Participants were given two simple questionnaires: The first one presented each position in a separate sheet, and asked whether participants felt that the position was a win for white, a win for black, or a draw. Participants were also asked to give the first move for white. This phase was intended to familiarize chess players with each position, as a preparation for the experiment. Positions were presented in the shuffled order in both questionnaires (i.e., according to our theory, position 1 should be matched with position 7, etc.). The matching predicted by our model is found in Table 1.

In the second phase, experts were presented two sheets containing all the 20 positions (in the same permuted order), and a third sheet containing the numbers 1,2, . . . ,20 in circular arrangement. Players were then told that their task was to find 10 pairings of those positions and to draw lines between their corresponding numbers. Players were specifically instructed to look for "similarities of strategic vision," "essence, not appearance," and their particular "feelings for how the positions will evolve strategically." No more instructions were given. It took participants around 20 min to match up the positions.

In the experiment, the main dependent variable under analysis is the number of matched pairs as suggested by the hypothesis that abstract roles determine similar strategic scenarios (i.e., matchings included in Table 1). Another dependent variable analyzed was the number of pairs stemming from the control group of positions.

Before we proceed to results, it is important to discuss how much a matching of 10 pairs is able to inform us. How reliable should those results be? Let us suppose an expert player finds the exact matching predicted by our "abstract role" theory of chunking in chess. What is the likelihood of that event happening by chance? If there is a high likelihood of such a "false-positive" result, then the robustness of the experiment would obviously be questionable. We thus analyze the underlying combinatorics of such pairings and compute the probability of such a false-positive result arising in our experiment. If there are N positions on a set, let us imagine that participants will choose any one of them and look for its pair. There are at this stage (N-1) positions to be paired with, so that when one is chosen we have (N-1) branches of this decision tree. Now, at the next step, there are (N-2) positions remaining. By the same reasoning, a participant will have (N-3) options to chose from, and thus the decision tree now holds (N-1)(N-3) end nodes. Because this reasoning extends for the entire set of positions, until there is only a single pair remaining, the equation counting the number of possible distinct pairings follows: For N positions, N being even, we have (N-1).(N-3).(N-5). . . . .(1) $= \prod_{i=1}^{N/2} (2i - 1)$ distinct pairing possibilities. The rapidly growing number of distinct possibilities is obviously a combinatorial explosion.

With 20 positions, a false-positive matching has the minuscule probability of occurrence of 0.00000000152735. It is exceedingly unlikely that a participant would come up with our predicted matching of 20 positions by chance, and the possibility vanishes should numerous participants find it independently.

2.5. Results

Given the prominence of POS information, traditional theories might expect match-ups between positions with higher POS co-incidences. Our theory, on the other hand, predicts that a large number of chess players would match the positions based on the roles that pieces play, not on the types of pieces, the number of pieces, or their specific board squares. In fact, 19 participants, representing 53% of our sample, matched the 20 positions precisely as expected by the theory. The chance of a false-positive result—that is, the probability of so many simultaneous match-ups—is smaller than 10^{-170}.

This makes it clear that, in the chess players' perspectives, there should be a high similarity, on the strategic vision level of what the essence of the position feels like—as opposed to the surface level of what the appearance of the position looks like. This strategic vision similarity would be due to the perception of the similar sets of abstract roles, which were used to create the set of positions in the first place.

Regarding the different participant groups on the two types of problems, we have the following findings: In the first participant group, formed by experts, 16 from 22 participants have correctly matched the 10 pairs expected by our theory, with a mean of 9.32 pairs (SD = 1.21). In the novice group, however, only 3 from 14 participants have correctly matched the 10 pairs expected by our theory, with a mean of 5 pairs (SD = 3.44).

In relation to the "control position groups" (i.e., exhibiting similar underlying structure as given by high POS matches; and highly different strategic structure), experts held a mean of 0.14 ($SD = 0.47$), whereas novices presented a mean of 1.71 ($SD = 1.82$). The measures of performance of the experts and novices on two types of problems are presented in Table 2.

Our theory would also predict that, as players advance to higher skill levels, players would be able to perceive previously unforeseen abstract roles, leading to the following hypothesis:

H1: There is a positive correlation between player ratings and pairings predicted by our theory.

To test this hypothesis, an analysis of variance (ANOVA) was carried out to measure whether the difference between the averages of the pairs matched as expected was statistically significant. The significance level used was 1% ($p < .01$). The results obtained show that more advanced players match more positions postulated by the theory and that the difference between groups is statistically significant, $F^{(1,34)} = 29.35$, $MS_e = 5.43$, $p < .01$.

Our theory also predicts that as players advance in skill level, they will be less likely to match superficially similar positions (on a POS basis):

H2: There is a negative correlation between player ratings and pairings from the control group of positions.

To test Hypothesis 2, another ANOVA was carried out to test whether the difference between the averages of the pairs matched in the control pairs was statistically significant. The significance level used was 1% ($p < .01$). The results obtained show that more advanced players match fewer control pairs then beginners, and that the difference between groups is statistically significant, $F^{(1,34)} = 15.26$, $MS_e = 1.40$, $p < .01$.

An important point concerns the relation between the familiarization phase of the experiment in which participants classified positions as win, draw, or lose, for white, and suggested moves, and the pairing judgments. It has been an established result for decades that higher skilled players were better at assessing win/draw situations and selecting abstract attacking themes (Charness, 1981a, b). This is further supported by our study in which participants unable to perceive the core dynamics of a position, as displayed by a wrong assessment and move suggestion, were also unable to point out the pairings expected by the theory. It is understandable, thus, that the higher the skill level, the higher the number of expected pairings—for participants that cannot meaningfully perceive *a single* strategic situation cannot be expected to perform better than chance in pointing out how that strategic situation may be similar to others.

Finally, it is vital to point out that the 3 unrated beginners included in this study matched four control pairs (out of 5) as "most similar strategically." Because these control positions share the highest number POS combinations, it seems plausible that novices have great difficulty perceiving the abstract relations that constitute the essence of a position, tending to become confused with surface appearances. Although this might seem a trivial remark, it might have implications for cognitive computational architectures.

Table 2

						99% Confidence Interval for Mean			
Problems	Groups	Subjects	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Pairs expected by theory	Experts	22	9.32	1.211	0.258	8.78	9.85	6	10
	Novices	14	5.00	3.442	0.920	3.01	6.99	0	10
Control positions (pairs)	Experts	22	0.14	0.468	0.100	0.07	0.34	0	2
	Novices	14	1.71	1.816	0.485	0.67	2.76	0	5

3. What role do chunks play?

What role do chunks play in chess perception? The classic response has been that their role is to encode POS combinations. We propose a complementary view in which chunks have many varying levels of encodings, from surface (syntactic, POS) information all the way up to deep (semantic, conceptual) structure given by abstract roles. Pieces perceived trigger potential trajectories, which trigger potential relations, which trigger potential roles that can be assumed in a board position (Linhares, 2005). At the opening, POS seems to dominate a player's attention, whereas during the middle and endgame phases, the abstract roles provide a source for priming potential forthcoming moves. We define chunks as semantic units formed temporarily to support a global, meaningful, perception of a situation—bringing cues to what might happen and how the situation might evolve.

Is there additional evidence from other domains that chunks encode abstract roles? During the last 15 years, a number of computational architectures from the Fluid Analogies Research Group have been developed to deal with these exact issues: the variability of surface information and the flexibility of conceptual, abstract, interpretation of percepts. A project has been devised, for instance, to deal with the monumental variability of font styles in which a letter is conceptualized as a set of abstract roles (Hofstadter & FARG, 1995; McGraw, 1995; Rehling, 2001). Another project has been devised to perceive abstract conceptual patterns in letter strings (Hofstadter & FARG, 1995; Marshall, 1999; Mitchell, 1993; Mitchell & Hofstadter, 1990). Objects on a dinner table, for example, have also shed light to our understanding of a person's perception of similarity (French, 1995). Finally, Bongard problems (Bongard, 1970; Foundalis, 2006; Hofstadter, 1979; Linhares, 2000) show the intricacies involved in the process of categories and concepts adapting to "a set of incoming stimuli and try[ing] to align themselves with it. The process of inexact matching between prior categories and new things being perceived . . . is analogy-making par excellence" (Hofstadter, 2001, p. 504).

French and Labiouse (2001) use essentially the same reasoning to show the limitations of a role-free approach in linguistics. For example, they ask an association (by co-occurrence of words) system to find a good candidate name for an Israeli prime minister. The system then searches in its enormous database of correlated terms for those proper names associated with "Israeli prime minister" and quickly produces results such as "Ariel," "Yitzhak," and "Benjamin." But, the system also produces terms such as "Saddam," or "Arafat." Because associations are devoid of abstract roles, the system is blind to the semantics underlying each term. French and Labiouse do not stop there, and further asked the system to, for example, "rate 'Lawyers' as 'sharks,' 'bastards,' and 'slimeballs.'" The results obtained are compared with human data. Because the system cannot perceive the, negative roles that lawyers are often seen (and caricatured) as playing in contemporary culture, it rates those matches as very low. In contrast, in human data, the rating skyrockets. Without perception of abstract roles, meaning vanishes: Can the reader conceive when "coffee cups are like old elephants?" (French, 1997).

This study on the chess domain is thus part of an arising theory of mind based on the idea that analogy is the core of cognition (Hofstadter, 2001) and that intelligence demands the perception of deep structure—in which bottom-up processes of raw data, surface-level, recognition cannot be separated from the flux of top-down, hypothesis-driven, conceptual processing. What lies, then, below high-level perception? The recognition of abstract semantic similarity, highly detached from surface features. And what gives rise to perception of abstract similarity? Processes of analogy making in which numerous surface features can differ, whereas an underlying abstract scheme remains still. What would this underlying scheme be, then? The abstract roles played by each surface datum. We note in passing that some, although not all, of these ideas have recently been proposed also as "role-based categories," by Markman and Stilwell (2001). The key role chunks play may be, well, to provide an interpretation of the role played by each datum and, therefore, to unify into a coherent whole disparate pieces perceived in isolation by giving the data a proper function to play in each context.

4. Conclusion

We have presented an experiment demonstrating that POS information is not sufficient to account for chess players' perception of a strategic situation. Two characteristics conspire to make POS information extremely important in chess. First, the initial position is fixed. Imagine a variation of the game in which the strong pieces were shuffled randomly. Because there would be over 1 billion initial positions, this variation would make memorization of opening strategies intractable and databases useless. The other characteristic is that the board is very small. If chess were to be played on a 40×40 board (perhaps with 40 pawns filling each of the 10th and 30th rank) and the usual eight strong pieces, then the *relative* position of pieces, and not the absolute one, would play a significant part from the start of the game. If chunks indeed encoded solely POSs, a distinct theory would be needed to account for our results and for those of Chabris and Hearst (2003) and McGregor and Howes (2002). POS information is necessary, but does not seem to be sufficient, to account for chess expertise.

The results presented here suggest that chess players with enough expertise can perceive strategic similarities between positions when similar abstract roles are found. This occurs even with positions that have different pieces, different numbers of pieces, different specific squares occupied on the board, different search trees (in depth or breadth), and so on. These results should come as no surprise if chunks are subordinated to the abstract roles that pieces and sets of pieces and empty squares hold on a position.

If chunks are built on the basis of abstract roles, then this should also explain the results obtained by McGregor and Howes (2002) in which the semantics of chessboards determined the response of participants. In fact, we argue that a satisfying theory of semantics, of meaningful perception, may be achieved through the study of the information processing involved in analogy-making, and on the perception of abstract roles. We propose that analogy making is the core information processing involved in chess cognition, as it is in other domains (Hofstadter 2001; Markman & Stilwell, 2001). This view is, obviously, very far from an established consensus between cognitive scientists. However, in what concerns expert pattern recognition in the chess domain, this may just turn out to be the case.

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5. Appendix

Positions (with commentary) used in the experiment:

Control positions 14, 15, 17, and 18. According to classical chunking theory, the vertically aligned positions should have greater similarity because they share higher numbers of pieces-on-squares. The bishops of same square colors (upper row) lead to a clear win for white, whereas the bishops of different colors (lower row) lead to a draw. The reader should note that a matching of 14 to 15 and 17 to 18, which was intentionally the order of presentation of the positions, would not correspond to the expectations held by the theory postulated in this article, but would be seen as more similar by the classical chunking theory models.

Control positions 11, 12, 13, and 19 used in the experiment. Once again, a single piece-on-square difference at the surface level, but a significant change at the strategic vision level.

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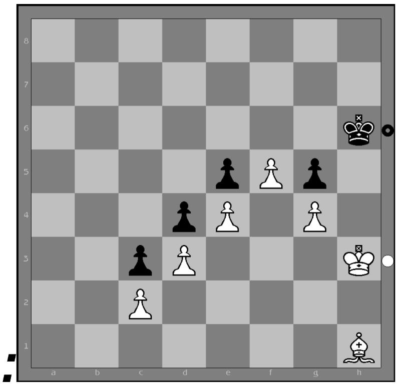

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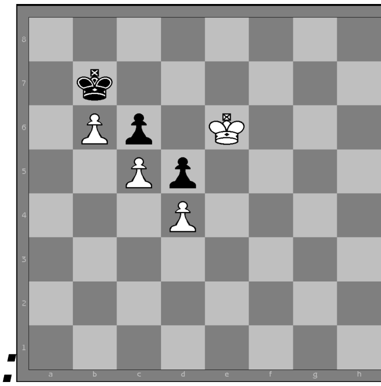

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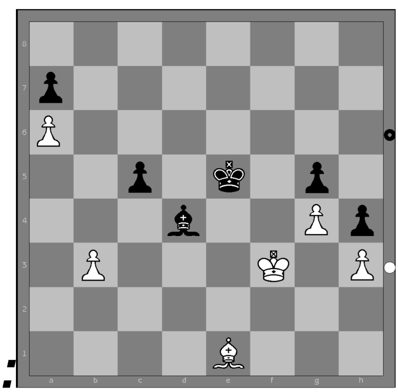

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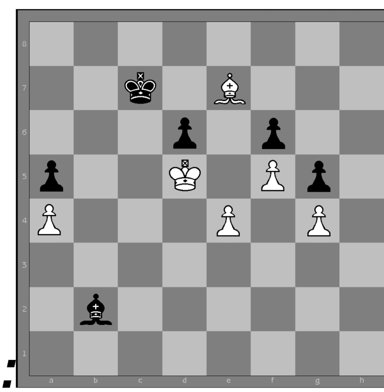

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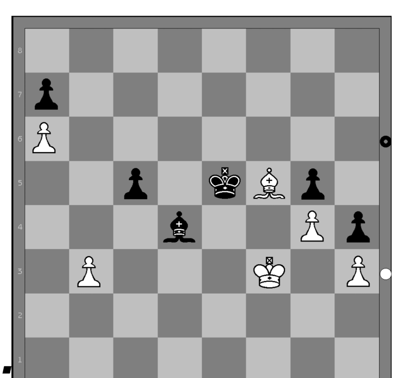

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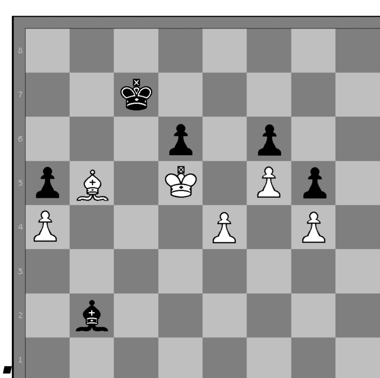
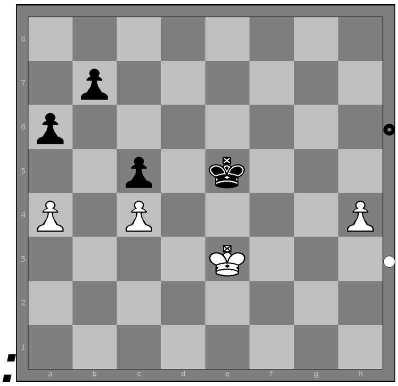
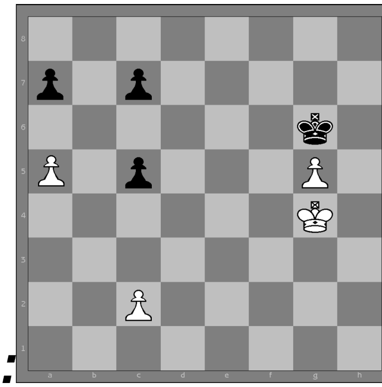
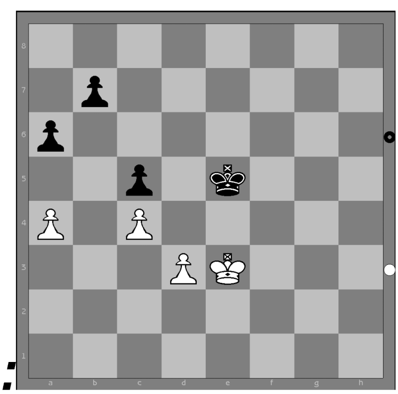
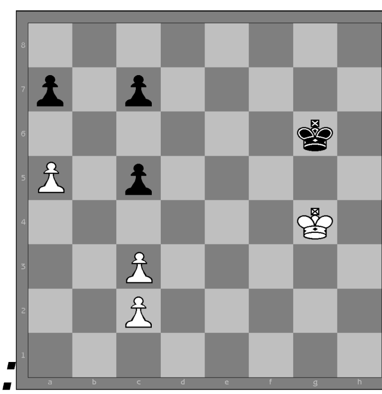


Here, the displacement of a single pawn radically changes expert players' perception on the strategic vision level. Positions in the upper row are seen to be a clear victory for white, whereas positions in the lower row are perceived to lead to a draw, and hence are perceived as more similar at the strategic vision level. (Expert players reported that position 13 seems rather difficult, but their feeling was that black could draw by defending c6—it is beside the point whether a master or grandmaster or advanced computer architecture could prove a win for

11: 

19: 

12: 

13: 

white, for we are investigating how experts feel about the position and not what the position is in an objective, game-theoretical sense.)

Positions 1, 2, 4, 5, 7, and 9. These are trivial positions, with no resemblance between pairs at a surface "appearance" level, but high resemblance at tactical and strategic levels. In positions 1 and 7, white moves a piece to a protected square and checkmates; in positions 2 and 4, white moves a piece to a square guarded by black to find a discovered checkmate; in positions 5 and 9, white has an absolute fork, which leads to significant material gain (5 and 9 are the positions that novices could most easily pair).

Position 3 is a control position, varying a single piece-on-square from position 6. Again, these positions do not share any single piece-on-square matching, but experts report that "they are extremely similar," and both of them lead to a clear draw.

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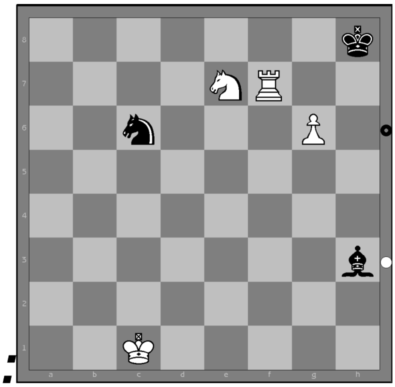

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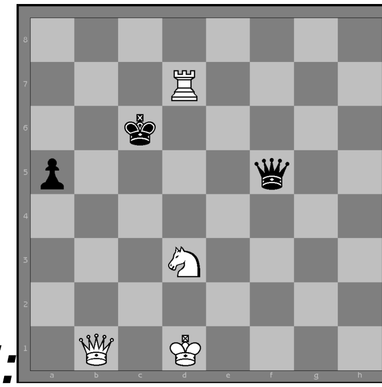

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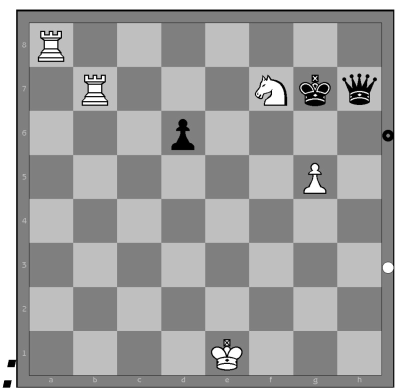

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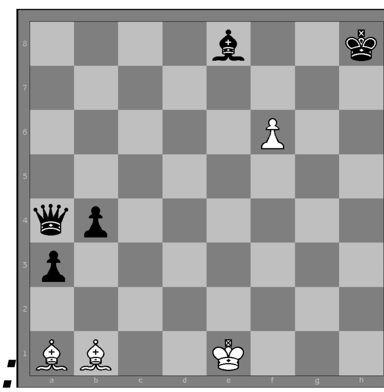

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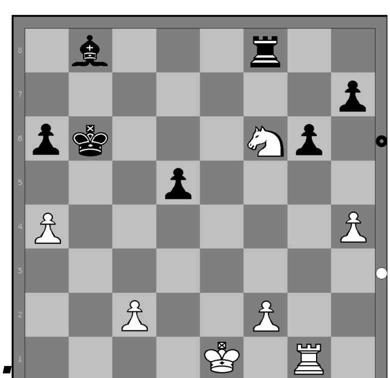

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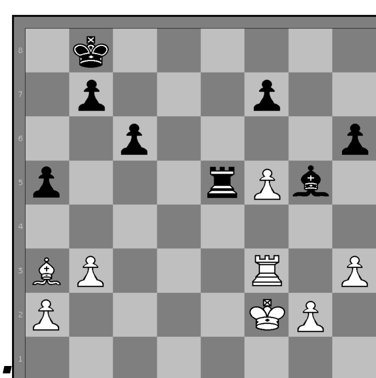

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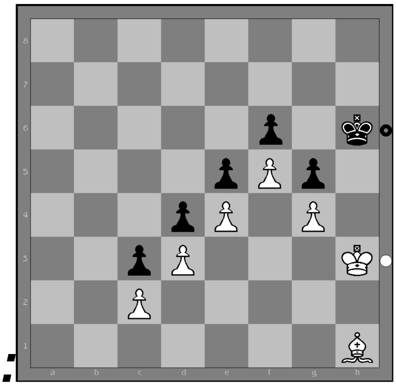

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