



# The emergence of choice: Decision-making and strategic thinking through analogies <sup>☆</sup>



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## ABSTRACT

Consider the chess game: When faced with a complex scenario, how does understanding arise in one's mind? How does one integrate disparate cues into a global, meaningful whole? How do players avoid the combinatorial explosion? How are abstract ideas represented? The purpose of this paper is to propose a new computational model of human chess cognition. We suggest that analogies and abstract roles are crucial to understanding a chess scenario. We present a proof-of-concept model, in the form of a computational architecture, which accounts for many crucial aspects of human play, such as (i) concentration of attention to relevant aspects, (ii) how humans may avoid the combinatorial explosion, (iii) perception of similarity at a strategic level, (iv) a state of meaningful anticipation over how a global scenario may evolve, and (v) the architecture's choice as an emergent phenomenon from the actions of subcognitive processes.

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## 1. Introduction

Most models of decision-making and strategic thinking are based on game-theoretical ideas. Yet, the human mind works in different ways from those postulated by game theory or expected utility theory. While game theory has provided us with valuable insights into numerous scientific fields, the assumption that humans think and act “rationally” as postulated does not stand empirical enquiry [4,38]. This paper makes some observations concerning how an alternative model might be. The objective is to present a model of decision-making and strategic thought that, while admittedly preliminary and consisting of a limited proof-of-concept, may shed light on the underlying cognitive processes, and influence further work on unexplored and perhaps promising avenues of research.

Our interest here is in the bridging the gap between strategic-interaction games, experimental psychology, and work on cognitive modeling. We will be particularly interested in the game of chess, a zero-sum combinatorial game for which extensive psychological knowledge has been acquired; and the main thrust of this work is to propose that the FARG models (for Fluid Analogies Research Group) provide a serious blueprint to modeling decision-making and abstract thought in games and strategic interactions.

A number of FARG models have been devised in order to better understand perception, massive parallelism, emergent understanding from subcognitive processes, the bottom-up and top-down interplay of these processes, and the central role of analogy in cognition.

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In this paper, a new computational model of chess decision-making is proposed, in the form of a computer architecture called Capyblanca. We also see how the Capyblanca project may be psychologically-plausible, gradually moving from low-level vision processing into high-level abstract reasoning.

### 1.1. The objective of this paper

Our interest here is on the following question: *how do chess players understand what is going on in a particular scenario?* A complete understanding of this question demands that the following scientific questions, currently without cogent explanations, be approached:

1. How can old strategies be applied to new situations?
2. When faced with a complex scenario, how does one integrate disparate cues into a global, meaningful, understanding of the situation?
3. How do humans avoid the combinatorial explosion?
4. What is an intuitive sense of a position? How are humans able to play rapidly at high-performance levels?
5. How can strategically similar positions be perceived? Which mechanisms and representation structures enable cognitive processes to perceive analogous positions that retain a shared essence?

These are the questions that guide this work. Though it is only a first step, a *proof of concept* of the ideas involved, and with obvious limitations, we make some observations concerning Capyblanca that may shed new light on these issues.

Consider question #1: *How can old strategies be applied to new situations?*

We postulate that *analogies play a key role in the understanding of a chess scenario*. Consider the positions shown on Fig. 1. Experts report that pairs (6,10) and (8,20) are ‘very similar’, despite the large number of superficial differences [25,26].

In positions 6 and 10, black cannot defend from the simultaneous attack of white’s passed pawn and king. Note that in position 6 the white king will move across the board, to eventually threaten the E5 pawn. These movements expand the game tree, involving over 20 plies. The decision tree of position 10, on the other hand, is shallow. To the “eyes” of a traditional tree-search program, these positions have *no similarity*, as only at the abstract level does their shared essence emerge. Yet, the strategic similarity to the situation in position 10 is remarkable, even with large differences in search tree depth and breadth.

Positions 8 and 20 involve exchanges. In position 8—a variant of a position used in Charness et al. [8]—, 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 positions display high strategic similarity and no similarity at a surface (“appearance”) level. Analogical mechanisms enable humans to perceive such abstract strategic similarities, and this enables the application of old strategies to new situations, as argued in [25,27–31].

### 1.2. What the paper is not

The objective of this paper is to point out a new model of chess cognition based on the psychology of chess and on FARG architectures. It is important to point out what this paper is not. The paper is focused on the innovations of Capyblanca, and not on other important topics addressed previously on the literature:

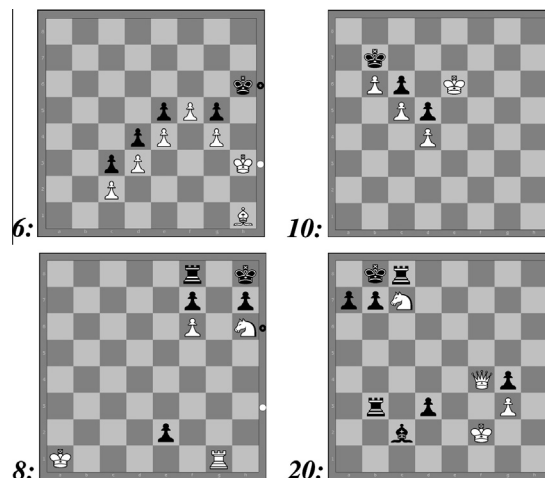


Fig. 1. White to move. Analogy enables the application of familiar strategies to new, unforeseen, situations.

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