Chess Metaphors

Artificial Intelligence and the Human Mind

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Preface
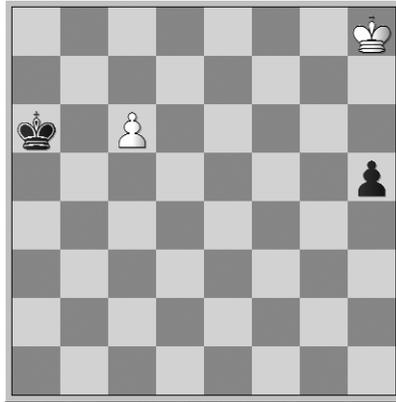
Gabriel looks at Alex. Alex smiles, provoking in his older brother a sponta-
neous laugh. Four-year-old Gabriel says, "Papi, Alex is little, and he doesn't
understand what you say." After that, we read a book. He looks at me with
admiration: "Papi, how can you do that?" "Do what?," I say with surprise.
"That," he says. "How can you know the end of the story?" I look tenderly at
him, as you do when contemplating the candid curiosity of a child, and gaze
at Alex too, who is still smiling, caught up in the world of a just-about-one-
year-old. The three of us laugh, and we wrestle on the sofa.

The same type of fascination that floods the mind of a child when he ob-
serves an adult performing trivial and everyday tasks with "such skillfulness"
is at the origin of this book. I am talking about the sense of awe that I feel
when following the games of the great chess players or the overwhelming
emotion that I felt when suddenly I understood Richard Reti's composition
(shown in the diagram above). I remember how on that occasion, I hardly
had time to show my own father how white can avoid losing thanks to the

geometry of the board (moving the king to the g7 square draws the game). But at many other times, I have been unable to comprehend all the subtleties that come in many of the moves, ideas, or strategic plans of the great players. In sum, I felt like my four-year-old son—in awe of a complexity (or simplicity) that escaped me.

My ability to know the ending of a child's story is something that few adults would consider surprising. In the same vein, the ability of a chess grand master (GM) to evaluate the position of the pieces on the board and predict where the pieces will be in the final position is a trivial matter for any expert player but not for those who don't know how to play chess or for players who do not have abilities beyond a certain level. The patzers who surround the chess tables of the local tournaments feel surprise after each move from the master—like children trying to understand how an adult knows that night follows day or that rain falls from the clouds. For most people, experts in any activity or human enterprise have abilities that are difficult to understand and easy to admire. But the mystery that envelops the enormous capacity of some people to carry out certain kinds of actions disappears with the acquisition of knowledge. We are all experts in something. Thanks to a long learning process, we can undertake incredible enterprises—from tying our shoelaces to solving differential equations. This capacity is the result of the never-ending curiosity of the human spirit, a curiosity that lies at the heart of this book.

How do we create this curiosity? Certain living beings, among them *Homo sapiens*, have a peculiar structure that we call the *brain*. Its presence allows them to explore the world through their five senses—touch, hearing, sight, smell, and taste. This happy union of perceptual and biological signal-processing elements is formed by an agglomeration of nervous tissue that, in turn, is formed by cells called *neurons* that specialize in the transmission of electrochemical information in the anterior end of the vertebrate animal (what we usually know as the head). The brain processes the stimuli that come from the outside world through our sense organs, elaborating pertinent responses that translate into action. To do that, the human brain employs remarkable resources. The memories stored in some cells of the nervous tissue are used as a comparative framework to the input stimulus, and the adequate integration of both inputs and framework is carried out in the form of thoughts that form meaningful responses.

For example, when we see a face, the visual information coming from our eyes stimulates certain areas of our brain, especially the occipital region (near the back of the neck) and the fusiform gyrus (in the temporal lobe), provoking a cascade of neural stimuli that elaborate amazingly varied kinds of

thoughts—such as curiosity ("Where have I seen this face before?"), admiration ("What a beautiful face!"), a mundane greeting ("Hi, how are you?"), or caution ("I better go to the other side of the street"). But to remember faces, words, grammar rules, colors, or sounds, it was necessary to learn at some point in time. When we recognize, for example, the beauty of a face, we experience certain feelings and sensations all over our body that are difficult to describe with words: they are emotions. Moreover, when we recognize a face, we also recognize ourselves in the past and in the present in a brain exercise we call *consciousness*. All these brain activities—memory, thought, emotion, consciousness—are some of the many activities that are part of what we call *cognitive processes*. Western philosophy and science have always talked about them in a vague and loose manner as a unique concept—the *mind*.

In chapter 1 of this book, I introduce relevant aspects of the structure and function of the human brain to prepare a solid foundation for a discussion of the organic patterns and processes that underlie cognitive processes. I focus on the cognitive task of problem solving: which mechanisms operate inside our body when we encounter a problem that needs to be solved? These key issues of the biology of human behavior are explored, as are areas of study that have emerged around the science of artificial intelligence (AI). Certain intimate relations are highlighted when one looks at the cognitive properties of the brain within the context of theoretical modeling. Thus, AI is used here as a comparative model—a metaphor of the structural and functional organization of the brain. Along with AI, another metaphor—the behavior of a chess player—brings a narrower, more precise focus to the descriptions and ideas analyzed in this book. The moves of the thirty-two chess pieces over the sixty-four squares of the chessboard will guide this journey of discovery, opening up fundamental questions and several surprises.

The choice of chess as a common thread in this journey is not random. Chess offers an ideal lab for testing and exploring cognitive processes. Furthermore, the founders of AI as a scientific discipline (people like Edward Feigenbaum, Marvin Minsky, Allen Newell, Claude Shannon, Herbert Simon, Alan Turing, John von Neumann, and Norbert Wiener, among others) realized that chess offered a challenge of great theoretical interest to try to simulate thought processes through computer programming. So the core idea of this book can be encapsulated as follows: I use chess to delve into an analysis of the cognitive properties of the brain. As it explores concept after concept, move after move, the book delves into the varied mental mechanisms and the respective cognitive processes underlying the action of playing a board game such as chess. First, chapters 1 and 2 explore the basic organic elements behind the construction of a mind, and chapter 3 analyzes

the formal contents of AI. Chapter 4 takes the game of chess into a bigger framework, analyzing collateral influences that spread along the improbable frontiers between games, art, and science. In chapter 5, I evaluate the results of AI's initial challenge—its search (with major programming efforts) for a computer that could beat chess grand masters and potentially become the next chess world champion. The book concludes with a critical analysis of such a challenge, examining why the real reach of this AI enterprise has been overstated when compared with the creative nature of the human brain.

The real world is not what it seems. This phrase, a common, everyday observation, encloses a deeper truth that suggests that accessing the world that surrounds us in a truly trustworthy way is impossible. The idea is part of the Western philosophical and scientific tradition, from Plato's cave to Heisenberg's uncertainty principle. Whether we are gazing at the long, flickering shadows of the allegorical cave or using tools that disturb the surrounding reality to analyze the minute particles that make up matter, we are condemned to hypothesize about the nature of the world. Worse still, according to Karl Popper, we are condemned to an inability to verify hypotheses. The problem of knowledge is how to formalize the possibility of recognizing an entity and then how to transmit its meaning in the best possible way. But knowledge just for oneself has little relevance. A few clues about the outer world are enough for survival, reproduction, and a peaceful and healthy existence. That is how most animals pass through the world, but almost all mammals and birds have elaborate behavioral organizations that lead them to form different types of associations. The human species is included in this group of social animals. As a part of our phylogenetic inheritance (*phylogeny* is the study of kinship relations among species with the implicit idea that these relations are due to evolution), the most complex social dynamics of evolutionary history have been generated—civilizations. Many invertebrate animals (like termites, ants, and bees) have also elaborated complex social relations, but they are far less sophisticated than the social hierarchies of birds and mammals.

Humans are, above all, cultural animals that have specialized in the acquisition and transmission of knowledge as if that were one more element of their biology. During the last thirty thousand years (at least), the human species has incessantly questioned its own nature and its position within the universe—an overwhelmingly empty enterprise because of the paucity of valid answers and always led by a search for religious meaning. Little by little, this search has been stripped of its divine sense as attitudes evolved through the influence of the scientific community and by the transformation of societies into modern nation-states. Thus, a huge role has been played by scientists.

Copernicus and Galileo showed that we are not the center of the universe, Darwin recognized the animal within our being, Freud placed consciousness at the center of the scientific quest, and Einstein equated matter with energy and showed nature's dependence on point of view. They helped generate a radical change in today's societies by promoting a spectacular turn away from the religious and toward the secular. But also important was a change of attitude that began with Enlightenment thinking in France and the United States of America at the end of the eighteenth century—a move toward the knowledge of reality and the conviction that the human being is but one participant in the world's natural landscape.

Chess is a cultural activity that originated somewhere in Asia in the second half of the first millennium CE. The next period of great development for chess was in the eighteenth and nineteenth centuries. Its growth paralleled the philosophical and scientific developments of the Enlightenment, especially in Central and Western Europe. It was perhaps the definitive thrust given by the cultural and artistic milieu of the nineteenth-century Romantic era that furnished chess with its present aura of intellectual and creative quality. Several cultural metaphors are embedded in chess—struggle as an echo of our animal nature (as the great Emmanuel Lasker put it), honesty, deceitfulness, bravery, fear, aggression, beauty, and creativity. Playing chess can resemble our attitudes about our daily lives and can sometimes take us beyond our personalities so that we can have on the board those dreams that the harsh reality of our lives forbids us. Chess is an activity that allows players to deploy almost all of their available cognitive resources. For this reason, chess is an ideal laboratory in which to start a journey into the diverse activities that are carried out by the mind and its physical correlates, including the ways that the brain functions and the body moves.

An analogy with biology can help to illustrate this last point. Research in biology is done with organisms that are considered models because they are easy to study for a variety of reasons. The data that we collect from these living models are generalized to other living beings. One of the most important of these models is the fruit fly (which has a more serious name—*Drosophila melanogaster*). Other important models are the bacteria *Escherichia coli*, the worm *Caenorhabditis elegans*, the frog *Xenopus laevis*, the chicken *Gallus domesticus,* and the mouse *Mus musculus*. The fruit fly has been cut in small pieces so that scientists can study the deepest corners of its anatomy, its sequence of embryonic development, the results of mutations in specific genes, and many, many other things. According to Neil Charness, chess is to cognitive science what *Drosophila* is to biology. Although Charness's optimism reflects more a wish than a reality, chess has been used for research in AI (which today is an

undisputed branch of cognitive science) since its beginnings in around 1950. It is a model for emulating intelligent behavior through the use of algorithms and heuristics programmed in computer systems.

One of the first goals of the pioneers of AI was to create a program that could play chess. The idea, somewhat naïve, or at least, simplistic, was that if chess is considered an entirely mental activity, the emulation of the game by means of an algorithm would implicitly mean the simulation of thought production. For Claude Shannon, the father of information theory, the development of a chess program was not in itself useful but did offer an enormous gain in understanding of the heuristic needed to solve problems. This gain would be translated into a surge in automatic systems for handling and manipulating data and for practical situations in the world. The evolution of artificial intelligence as a research field shows that this move has been made from research on systems like chess to expert systems that have been used on a multitude of occasions to improve and automate tasks (from medical diagnosis to weather forecasting, two clearly useful examples).

From its beginnings in the mid-1950s, artificial intelligence as a scientific discipline has provoked debates about the nature of its name. Indeed, the idea that a kind of "artificial" intelligence exists seems somewhat absurd if one considers that the creation of this science is a cultural achievement of human beings: there is nothing artificial about it. But more important still is the definition itself of *intelligence* as a characteristic of the human mind that can be handled in descriptive and operative terms. The problems are multiple—from the possible existence of several types of intelligence (so that it might be possible to speak of multiple artificial intelligences depending on the type of intelligence that is being modeled or used in the simulator) to the conceptual impossibility of generating a behavior that can come close to intelligent human behavior (the problem of the semantic content of human knowledge versus the merely syntactic content of a computer program, made evident by John Searle in his Chinese room metaphor).

Why use models and simulations? The answer is simple: models are the foundation of knowledge. Every scientific theory is based on models of reality that approximate it to a greater or lesser degree. The first model of reality is language itself, where the symbolic capacity of humans to represent the world rests. It is not easy to break the barrier of language so that the knowledge generated about a given problem or parcel of the world escapes the restrictions imposed by words, as Michel Foucault masterly showed in *Les mots et les choses (The Order of Things)*. In ancient Greece, philosophers began to use models of nature that transcended words. These models were based on formal structures of diverse characteristics that constitute metalanguages of

the representation of reality that have been preserved until today, although they have been so reworked that it is difficult to recognize them. The most important of these models are Pythagorean numbers, Aristotelian logic of predicates, and deductive Euclidian algorithms. Toward the end of the Renaissance, the numerical-mathematical models made their appearance, and thanks to their prediction powers, they fortified the development of science. Galileo, Descartes, Newton, Leibniz, and later, Ludwig Boltzmann, Einstein, and Turing (to name a few) used mathematical structures to model their parcels of reality. With Kurt Gödel, we find in the twentieth century the idea that formal systems are incomplete, a concept that is perhaps important to chess theory. If undecidable statements exist in chess, then it is impossible to solve them completely with a computer chess program.

Artificial intelligence falls within this scientific tradition, taking the field of modeling to a concrete parcel of the world—the brain. As such, it is a science that promises rewards within the history of human knowledge. Indeed, if we could manage to model the ways that we represent the world, put into practice our own capacity for introspection, and generate language, thoughts, emotions, and dreams—in short, that lengthy etcetera that we sometimes call *human consciousness*—it is likely that we would be able to finally approach answers to one of the deepest questions that the human species has always considered: who are we? In this sense, the main thesis that I propose in this book makes of chess a mental activity that can be modeled as a departure point for better understanding how the human mind works. The development of chess programs constitutes a field that has combined many of these perspectives—from the first attempts to emulate the mental processes of a game to the massive parallel searches within the tree of possibilities that are generated during play. The cognitive sciences (disciplines such as psychology, neurobiology, philosophy of the mind, and artificial intelligence) have influenced the systematic study of processes such as attention, knowledge, reasoning, logic, intelligence, information, memory, and perception, using the expert chess mind as a study metaphor.

On the surface, chess is a game that has a winner and a loser. However, a deeper look reveals that perhaps chess is not just a game but a line of communication between two brains. This hypothesis shapes the contents of the entire book: chess is a communication device. As with any other act of communication, it is necessary to have someone who sends the message, a transmission medium, and someone who receives the message. Players are both the communicators and receivers; the board and the chess pieces are the transmission medium. In an exchange of messages, ideas, attitudes, and personal positions about the uncertainty of our world, however, where is

the win, and where is the loss? Another hypothesis complements the first one: human beings are always involved in situations where they must act as sources or receivers of information. Now the landscape begins to make sense. Perhaps chess is a game. But the life of a human being is also a game. All social activities in which a human being must become an information source and receiver have a series of factors in common. There is always something to communicate (moods, annoyances, happiness, feelings, ideas). There is always something that we need to understand (a noise, a color, a sign, a danger, an emotion). There is always some medium that is familiar to us (a grammar, an artistic language, a chess board).

The style of this book is personal. My scientific and academic background leads me to search for answers to every question and furthermore to look for the scientific answer. As a human enterprise, however, chess departs from science to reach into areas such as individual desires and social convention. I have tried to use language that is not too scientific to clarify some ideas. I also have tried to avoid bibliographic references. By noting just the names of certain authors, I hope to spare the reader never-ending parentheses that often are only obstacles to following ideas. Instead, a partially annotated bibliography lists the most important references that I used for each chapter. The first two chapters are the most biological ones and therefore the hardest for the nonspecialized reader. Chapter 1 introduces the biological bases of thinking, exploring the structure and function of the brain, while chapter 2 deals with contemporary ideas about the nature of the mind and cognitive processes, and chapter 3 presents AI as a brain and mental processes modeling tool. Chapter 4 is an introduction to chess as a human activity that justifies its choice as a model for the elaboration of cognitive theories, and chapter 5 describes the functioning of a chess computer program, its most relevant components, and the ways that the Internet is changing how people in the chess community relate to each other. After the epilogue, which includes some final reflections about the nature of chess, three appendixes present some important chess concepts, information about chess programs, and popular Internet sites. For the reader who is not familiar with chess, I recommend reading the appendixes first or consulting them whenever some concept related to the game is not sufficiently clear. Some sections of the book are necessarily technical, and readers should feel free to flip through parts that seem *too* technical, with the idea that reading should be a pleasure rather than a guilty obligation.

As a final word, I offer an answer to the following, quite natural, question: why have I written this book? Basically, I have put together in a single volume those ideas, elements, facts, visions, and surprises that I would have loved to

find in a bookstore more than twenty years ago. I've tried to put chess within a framework that is larger than the game itself and that would help me to understand its reach as a cultural proposal, an elaboration of the mind, and a vehicle for understanding how the brain works. I have tried to relate the world that surrounds the effervescent task of playing a game of chess with human biology. I hope that the narrative and the metaphors that I have used transmit the fascination that I feel about chess to the readers who now have this book in their hands. If I have helped to reshape chess in new dimensions within the natural world and within the promising scenarios of AI, I have fulfilled my objective. The effectiveness of a gambit is always unknown. Only time tells players if they are right.

Diego Rasskin-Gutman
California, Spring 2005

Three years have passed since the first Spanish edition of *Chess Metaphors: Artificial Intelligence and the Human Mind* saw the light of day. The chess world, the AI world, and the brain/mind world have all evolved in new directions. Other books have joined this one, including *The Immortal Game* by journalist David Shenk, a stupendous account of chess, including a long section on cognition. Garry Kasparov has exited the chess scene to enter politics and has written *How Life Imitates Chess*. Viswanathan Anand is now the reigning chess champion. My sixteen-year-old nephew, Iván, drew him in a simul back in 2007 playing black with a king's Indian defense. I am proud of him. But what really caught my attention was an old book that I stumbled on two years ago—*Homo Ludens*, written in 1938 by the Dutch academic Johan Huizinga. This amazing book is an account of how games and playing have been culture generators throughout history, not just in obvious ways but rather as fundamental pillars that sustain the bases of societies. Although Huizinga did not include chess in his analysis, I was astonished at the similarities between the general mood of my book and Huizinga's thesis. If anything, it reassured me in my view that chess, as the noblest of games and as one nurtured by a plethora of cognitive processes, is to the human condition as brains are to the emergence of minds.

   I am grateful to The MIT Press for providing the venue and the means to translate my book and especially to Robert Prior, who believed in this project from the beginning and helped me through the initial review process, and Ada Brunstein for her support and understanding.

   Several things are different in this English edition. I have not included Adriaan de Groot's famous protocols, published in *Thought and Choice in*

Chess, because they can be easily accessed by the English-speaking community. Chapters 3 and 5 have been expanded with new sections on bioinspired strategies in AI and bioinspired approaches to chess computing. This last change was suggested by one of the reviewers, to all of whom I am also grateful.

The translation has been carefully crafted by my wife, Deborah Klosky. She has done a superb job of deciphering some obscure passages that not even I was sure about. My sons, Gabriel and Alex, are now seven and four, and Gaby knows the endings of many stories and most of the details of the seven volumes of Harry Potter, which he has read at least a couple of times. Now it is Alex's turn to wonder in awe about the same questions that Gaby had three years ago. We still end up laughing, and we wrestle on a (different) sofa.

Valencia, May 2008