



Lorenzo Magnani

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Abductive Cognition

The Epistemological and Eco-Cognitive
Dimensions of Hypothetical Reasoning



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Editors: Rüdiger Dillmann · Yoshihiko Nakamura · Stefan Schaal · David Vernon

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To my daughter Giovanna

How was it that man was ever led to entertain that true theory? You cannot say that it happened by chance, because the possible theories, if not strictly innumerable, at any rate exceed a trillion – or the third power of a million; and therefore the chances are too overwhelmingly against the single true theory in the twenty or thirty thousand years during which man has been a thinking animal, ever having come into any man's head. Besides, you cannot seriously think that every little chicken, that is hatched, has to rummage through all possible theories until it lights upon the good idea of picking up something and eating it. On the contrary, you think the chicken has an innate idea of doing this; that is to say, that it can think of this, but has no faculty of thinking anything else. The chicken you say pecks by instinct. But if you are going to think every poor chicken endowed with an innate tendency toward a positive truth, why should you think that to man alone this gift is denied?

Charles Sanders Peirce

Preface

This volume explores abductive cognition, an important but, at least until the third quarter of the last century, neglected topic in cognition. It integrates and further develops ideas already introduced in a previous book, which I published in 2001 (*Abduction, Reason, and Science. Processes of Discovery and Explanation*, Kluwer Academic/Plenum Publishers, New York).

The status of abduction is very controversial. When dealing with abductive reasoning misinterpretations and equivocations are common. What are the differences between abduction and induction? What are the differences between abduction and the well-known hypothetico-deductive method? What did Peirce mean when he considered abduction both a kind of inference and a kind of instinct or when he considered perception a kind of abduction? Does abduction involve only the generation of hypotheses or their evaluation too? Are the criteria for the best explanation in abductive reasoning epistemic, or pragmatic, or both? Does abduction preserve ignorance or extend truth or both? How many kinds of abduction are there? Is abduction merely a kind of “explanatory” inference or does it involve other non-explanatory ways of guessing hypotheses?

The book aims at increasing knowledge about creative and expert inferences. The study of these high-level methods of abductive reasoning is situated at the crossroads of philosophy, logic, epistemology, artificial intelligence, neuroscience, cognitive psychology, animal cognition and evolutionary theories; that is, at the heart of cognitive science. Philosophers of science in the twentieth century have traditionally distinguished between the inferential processes active in the logic of discovery and the ones active in the logic of justification. Most have concluded that no logic of creative processes exists and, moreover, that a rational model of discovery is impossible. In short, scientific creative inferences are irrational and there is no “reasoning” to hypotheses. On the other hand, some research in the area of artificial intelligence has shown that methods for discovery could be found that are computationally adequate for rediscovering – or discovering for the first time – empirical or theoretical laws and theorems.

Moreover, the study of diagnostic, visual, spatial, analogical, and temporal reasoning has demonstrated that there are many ways of performing intelligent and creative reasoning that cannot be described with only the help of classical logic. Abduction is also useful in describing the different roles played by the various kinds of medical reasoning, from the point of view both of human agents and of computational programs that perform medical tasks such as diagnosis. However, non-standard logic has shown how we can provide rigorous formal models of many kinds of abductive reasoning such as the ones involved in defeasible and uncertain inferences. Contradictions and inconsistencies are fundamental in abductive reasoning, and abductive reasoning is appropriate for “governing” inconsistencies. In chapter two many ways of governing inconsistencies will be considered, ranging from the methods activated in diagnostic settings and consistency-based models to the typical ones embedded in some form of creative reasoning, the interpretations in terms of conflicts and competitions to the actions performed on empirical and conceptual anomalies and from the question of generating inconsistencies by radical innovation to the connectionist treatment of coherence.

In 1998 Jaakko Hintikka had already contended that abduction is the “fundamental problem of contemporary epistemology”. My aim is to combine philosophical, logical, cognitive, eco-cognitive, neurological, and computational issues, while also discussing some cases of reasoning in everyday settings, in expert inferences, and in science. The main thesis is that abduction is a *basic* kind of human cognition, not only helpful in delineating the first principles of a new theory of science, but also extremely useful in the unification of interdisciplinary perspectives, which would otherwise remain fragmented and dispersed, and thus devoid of the necessary philosophical analysis. In sum, the present book aims at having a strong interdisciplinary nature, encompassing mathematical and logical cases, biological and neurological aspects and analysis of the epistemological impact of the problems caused by the “mathematical physics” of abduction.

The interdisciplinary character of abduction is central and its fertility in various areas of research is evident. The book also addresses the central epistemological question of hypothesis withdrawal in science by discussing historical cases (chapter two), where abductive inferences exhibit their most appealing cognitive virtues. Finally, an interesting and neglected point of contention about human reasoning is whether or not concrete manipulations of external objects influence the generation of hypotheses, for example in science. The book provides an in-depth study of what I have called manipulative abduction, showing how we can find methods of constructivity in scientific and everyday reasoning based on external models and cognitive and epistemic mediators.

The book also illustrates the problem of “multimodal abduction”, recently pointed out by Paul Thagard, which refers to the various aspects of abductive reasoning, neurological, verbal-propositional, sentential, emotional and manipulative. Multimodal abduction is also appropriate when taking into account the dynamics of the hybrid interplay of the aspects above and the

semiotic role played by what I call “semiotic anchors”. These anchors constitute ways of favoring hybrid reasoning in various cognitive and epistemic tasks and they play an important role in that event of “externalization of the mind” that researchers such as Andy Clark, Edwin Hutchins, Steven Mithen and others have labelled in various ways, ultimately resorting to the idea of the importance of the external cognitive tools and mediators in cognition. The book provides some case studies derived from the history of discoveries in science, logic, and mathematics, also taking advantage of the agent based perspective” proposed by Dov Gabbay and John Woods.

A central target has been to further study the concept of non-explanatory and instrumental abduction, introduced by Gabbay and Woods in their *GW*-model of abduction (a model they contrast with the *AKM*-model, previously proposed by myself, Atocha Aliseda, Theo Kuipers, Ant Kakas and Peter Flach, and Joke Meheus). Non-explanatory and instrumental aspects of abduction (together with the distinction between propositional and strategic plausibility in hypothetical reasoning) have to be discussed and further clarified, especially because they play a crucial role in scientific, mathematical, and logical abduction.

The first chapter, *Theoretical and Manipulative Abduction. Conjectures and Manipulations: the Extra-Theoretical Dimension of Scientific Discovery*, provides an illustration of the main distinctions concerning abductive reasoning concerning creative and selective, theoretical and manipulative abduction, and its primal explanatory character. The significance of the original syllogistic framework proposed by Peirce is also explained together with the status of some recent logical models of abduction. Moreover, some sections introduce the extra-theoretical dimension of scientific reasoning, with the help of the concept of model-based and manipulative abduction. Creativity and discovery are no longer seen as mysterious irrational processes, but, thanks to constructive accounts, they appear as a complex relationship among different inferential steps that can be clearly analyzed and identified. The last part of the chapter is devoted to illustrating the problem of the extra-theoretical explanatory dimension of reasoning and discovery from the perspective of some mathematical cases derived from calculus, where internal and external aspects (optical diagrams) of cognition are at play.

The second chapter, *Non-Explanatory and Instrumental Abduction. Plausibility, Implausibility, Ignorance Preservation*, analyzes and criticizes the difference between *GW*-model and *AKM*-model by providing a strict examination of the contrast between explanatory, non-explanatory, and instrumental abduction. Case studies derived from the field of the epistemology of physics, from logic and from mathematics are studied because they are particularly useful to further illustrate the non-explanatory and instrumental aspects of abductive cognition. The issue of instrumental abduction is especially important when intertwined with the exquisite epistemological problem of the role of unfalsifiable hypotheses in scientific reasoning. The role of contradictions,

inconsistencies and preinventive forms, and of the computational “automatic abductive scientists” in abductive cognition is also addressed.

The last part of the chapter is devoted to illustrating the problem of the extra-theoretical dimension of cognition from the perspective of the famous discovery of non-Euclidean geometries. This case study is particularly appropriate to the present chapter because it shows relevant aspects of diagrammatic abduction, which involve intertwined processes of both explanatory and non-explanatory abduction acting at the model-based level in what I call mirror and unveiling diagrams. Finally, the last section also deals with the epistemologically some very interesting computational AI applications expressly devoted to the simulation of geometrical reasoning.

The main concern of the third chapter, *Semiotic Brains and Artificial Minds. How Brains Make Up Material Cognitive Systems*, is to furnish an integrated analysis of the abductive processes from an updated epistemological and cognitive/semiotic point of view. Creative abductive reasoning is a risky sort of inference that constitutes a central process in conceptual change in science, mathematics, and logic. Its embodied and distributed aspects and its role in what I call epistemic mediators constitute a central issue of this chapter. Part of the chapter is devoted to the analysis, at a cognitive, neurological, semiotic and epistemological level, of the “externalization of the mind” also considering some classical insights furnished by Turing in the article “Intelligent Machinery” (1948) and some conclusions derived from the paleoanthropological research on what Steven Mithen has called “disembodiment of the mind”. The related concepts of mimetic and creative representations and of “mimetic mind” are introduced and explained; a further examination of the problem of on-line and off-line intelligence, in the framework of the relationship between language and inner rehearsal, is provided. The chapter also illustrates abduction from a dynamic perspective and the abductive process of external diagrammatization and iconic brain coevolution, with the help of some mathematical examples. A final scrutiny of the epistemological status of the psychoanalytic concepts of projection and introjection and of psychic externalized “symbols” is accomplished, aided by the concept of manipulative abduction.

In the fourth chapter, *Neuro-Multimodal Abduction. Pre-Wired Brains, Embodiment, Neurospaces*, starting from the results illustrated in the previous chapters regarding the fact that abductive cognition is occurring in a “distributed” framework and in a hybrid way, that is in the interplay between internal and external signs, I contend that we can reconceptualize abduction neurologically. From this perspective abduction is a process in which one neural structure representing the explanatory target generates another neural structure that constitutes a hypothesis. A whole neuro-multimodal framework is depicted, aiming at increasing knowledge about the fact that the classical perspective on abduction, based on logic only, captures limited properties of this cognitive process and considerably disregards model-based aspects. The neuro-multimodal perspective also aims at: i) clarifying the

distinction between the hardwired and pre-wired/plastic aspects of abduction; ii) a new understanding of some features of the problem of action and decision in formal reasoning, where a new integrated perspective on action can be worked out, taking advantage of the distinction between thought and motor action, which are both seen as the fruit of brain activity; ii) analyzing the role of abduction in the fundamental mammalian model-based cognitive activities, which relate to representation of object locations within the spatial/pseudo-geometrical framework. A final section is devoted to some philosophical issues arising from the traditions of phenomenology and psychology that are of special interest in elucidating some features of visual and spatial abduction.

Chapter five, *Animal Abduction. From Mindless Organisms to Artifactual Mediators*, is mainly dedicated to clarifying the Peircean originary conflict between the view of abduction as inferential as opposed to instinctual. The first two sections address this puzzling Peircean problem trying to show how his research was anticipatory of central problems and topics of present cognitive science research. Some speculations concerning abduction in terms of the dichotomies between perception and inference, iconicity and logicity, instinct and strategies, should just be admired and closely studied. These basic insights naturally led me to analyze the problem of animal abduction, which represents the other main theme of the chapter. Many animals – traditionally considered “mindless” organisms – make up a series of signs and are engaged in making, manifesting or reacting to a series of signs. Through this semiotic activity – which is fundamentally model-based – they are engaged in “being cognitive agents” and therefore in thinking “intelligently”. An important effect of this semiotic activity is a continuous process of “hypothesis generation” that can be seen at the level of both instinctual behavior, as a kind of “hard-wired” cognition, and representation-oriented behavior, where nonlinguistic pseudothoughts drive a plastic model-based cognitive role. This activity is at the root of a variety of abductive performances, which are also analyzed in the light of the concept of affordance, further explored in chapter six. Another important character of the model-based cognitive activity above is the externalization of artifacts that play the role of mediators in animal, languageless, reflexive thinking. The interplay between internal and external representations exhibits a new cognitive perspective on the mechanisms underlying the semiotic emergence of abductive processes in important areas of model-based thinking of mindless organisms. To illustrate this process I also take advantage of the case of affect attunement, which exhibits an impressive case of model-based communication, of the problems of pseudological and reflexive thinking and of the role of pseudoexplanatory guesses in animal plastic cognition.

The title of chapter six is *Abduction, Affordances, and Cognitive Niches. Sharing Representations and Creating Chances through Cognitive Niche Construction*. As a matter of fact, humans continuously delegate and distribute cognitive functions to the environment to lessen their limits. They build

models, representations, and other various mediating structures, that are considered to aid thought. In doing these, humans are engaged in a process of cognitive niche construction. In this sense, I argue that a cognitive niche emerges from a network of continuous interplays of hypothetical cognition between individuals and the environment, in which people alter and modify the environment by mimetically externalizing fleeting thoughts, private ideas, etc., into external supports. Hence, cognitive niche construction may also contribute to making a great portion of knowledge available that would otherwise remain simply unexpressed or unreachable. Abductive cognition is a central driver of those designing activities that are closely related to the process of so-called “niche construction”. The exploitation of this basically biological concept seems useful to study all those situations that require the transmission and sharing of knowledge, information and, more generally, cognitive resources. Further, some issues concerning the process of transmission and selection of the extragenetic information that is embedded in cognitive niche transformations are considered and their supposed loosely Darwinian character is stressed.

In dealing with the exploitation of cognitive resources embedded in the environment, the notion of affordance, originally proposed by James J. Gibson to illustrate the hybrid character of visual perception, together with the proximal/distal distinction described by Egon Brunswik, are relevant. In order to solve various controversies on the concept of affordance and on the status of the proximal/distal dichotomy, I will take advantage of some useful insights that come from the study on abduction. Abduction may also fruitfully describe all those human and animal hypothetical inferences that are operated through actions made up of smart manipulations to both detect new affordances and to create manufactured external objects that offer new affordances/cues.

Chapter seven, *Abduction in Human and Logical Agents. Hasty Generalizers, Hybrid Abducers, Fallacies*, addresses the problem of logical models of abduction, already introduced in the first chapter. This chapter presents the problem in an agent-based perspective. It is acknowledged that intellectual artifacts like “logical agents” are “ideal” tools for thoughts as is language. These are tools for exploring, expanding, and manipulating our own minds so that creative abductive “new ways of inferring”, performed by the “biological” human agents, arise in an unexpected and distributed interplay between brains (and their internal representations) and external representations. The analysis of this issue demonstrates further results regarding the following problems: i) deductive reasoning involves the employment of logical rules in a heuristic manner, even maintaining the truth preserving character: the application of the rules is organized in a way that is able to recommend a particular course of actions instead of another one. Moreover, very often the heuristic procedures of deductive reasoning are performed by means of an “in-formal” (often model-based) abduction; ii) in an agent-based framework fallacies can be redefined and considered as good ways of reasoning; we can

hypothesize that what I call manipulative abduction can be re-interpreted as a form of practical reasoning a better understanding of which can furnish a description of human beings as hybrid thinkers in so far they are users of ideal (logical/mathematical) and computational agents; iii) abduction can be seen in an extended eco-logical perspective in so far as it is involved in dialectic processes, where, as a fallacy – from the classical logical perspective, it is exploited in a “distributed” cognitive framework, where epistemic (but also moral) conflicts and negotiations are normally at play.

The last chapter, *Morphodynamical Abduction. Causation of Hypotheses by Attractors Dynamics*, presents some central epistemological, semiotic, and cognitive aspects of what can be called morphodynamical abduction in the perspective of dynamical systems in physics and catastrophe theory in mathematics. Indeed, an integration of the traditional computational view with some ideas developed inside the so-called dynamical approach can suggest some important insights. What is the role of abduction in the dynamical system approach? What is the role of the dichotomy salient/pregnant mathematically depicted by the catastrophe theory with respect to abduction? What is embodied cognition from the point of view – so to say – of its “mathematical physics”? To grasp the role of abduction in these scientific traditions I provide an analysis of the concepts of anticipation, adumbration, attractor, and of the dichotomy salient/pregnant: the result is the description of the abductive generation of new hypotheses in terms of a catastrophic rearrangement of the parameters responsible for the behavior of the system. The main concern of the part of the chapter devoted to the catastrophe theory is to demonstrate that pregnancies and saliences provide a further help in increasing knowledge about abductive “hypothesis generation” at the level of both instinctual behavior and representation-oriented behavior, where non-linguistic features drive a “plastic” model-based cognitive role. Furthermore, in terms of dynamic systems and of Thom’s mathematical modeling we reach a first sketch of a “physics of abduction”, where its cognitive essence is seen in a whole unified naturalistic framework where all phenomena, and so cognition, gain a fundamental eco-physical significance, which also nicely includes some aspects related to a kind of “social epistemology”.

A related problem is treated in section 8.6, which illustrates the so-called coalition enforcement hypothesis, which sees humans as self-domesticated animals engaged in a continuous hypothetical activity of building morality, incorporating punishing policies at the same time. Abduction is still at stake, the direct consequence of coalition enforcement being development and the central role of cultural heritage (morality and sense of guilt included). The long-lived and abstract human sense of guilt represents a psychological adaptation which abductively anticipates the appraisal of a moral situation in order to avoid becoming a target of coalitional enforcement.

I started to think upon the research to be exposed in this second book on abduction in 2001 while I was a visiting professor at Georgia Institute of Technology in Atlanta. In addition to my work here in Italy, I further reshaped the

manuscript in 2003 as a Weissman Distinguished Visiting Professor at The City University of New York, which provided an excellent work environment, and during visits to the Department of Philosophy of Sun Yat-sen University, in Guangzhou (Canton), P.R. China, where I was visiting professor from 2005 to 2008. These visits added an excellent source of further research and forged strong academic relationships with Asian colleagues, adding to those in the EU and USA. I am grateful to all my colleagues there and in other Universities worldwide for their helpful suggestions and much more. For valuable comments and discussions on a previous draft and about abduction I am particularly grateful to the two anonymous referees and to John Woods, Paul Thagard, Michael Leyton, Dov Gabbay, Claudio Pizzi, Emanuele Bardone, David Gooding, Atocha Aliseda, John Josephson, Walter Carnielli, B. Chandrasekaran, Jon Williamson, Eliano Pessa, Gianluca Introzzi, Douglas Walton, Cameron Shelley, Sami Paavola, Woosuk Park, Giuseppe Longo, Thomas Addis, Diderik Batens, Joke Meheus, Simon Colton, Gerhard Schurz, Ilkka Niiniluoto, Theo A. F. Kuipers, Ryan D. Tweney, Peter Flach, Antony Kakas, Oliver Ray, Akinori Abe, Luis A. Pineda, A. Shimojima, P. Langley, Demetris P. Portides, Tommaso Bertolotti. Some sections of chapters one, six, seven, and eight have been written in collaboration with my former Ph.D. students: section 1.7 with Riccardo Dossena, sections 6.1.1, 6.1.2 and 6.2-6.6 with Emanuele Bardone, sections 7.4.2 with Elia Belli, and section 8.1 with Matteo Piazza. The research related to this volume was supported by grants from the Italian Ministry of University, University of Pavia, and the CARIPLO Foundation (Cassa di Risparmio delle Provincie Lombarde). The preparation of the volume would not have been possible without the contribution of resources and facilities of the Computational Philosophy Laboratory (Department of Philosophy, University of Pavia, Italy). This project was conceived as a whole, but as it developed various parts have become articles, which have now been excerpted, revised, and integrated into the current text. I am grateful to Springer for permission to include portions of previously published articles.

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Lorenzo Magnani

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