Abductive Reasoning: Challenges Ahead

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ABSTRACT: The motivation behind the collection of papers presented in this THEORIA forum on Abductive reasoning is my book *Abductive Reasoning: Logical Investigations into the Processes of Discovery and Explanation*. These contributions raise fundamental questions. One of them concerns the conjectural character of abduction. The choice of a logical framework for abduction is also discussed in detail, both its inferential aspect and search strategies. Abduction is also analyzed as inference to the best explanation, as well as a process of epistemic change, both of which challenge the argument-like format of abduction. Finally, the psychological question of whether humans reason abductively according to the models proposed is also addressed. I offer a brief summary of my book and then comment on and respond to several challenges that were posed to my work by the contributors to this issue.

Keywords: abduction, abductive inference, discovery, heuristics.

A Summary

In *Abductive Reasoning: Logical Investigations into Discovery and Explanation*, I offer a logical analysis of a particular type of scientific reasoning, namely abduction, that is, reasoning from an observation to its possible explanations. This approach naturally leads to connections with theories of explanation and empirical progress in the philosophy of science, to computationally oriented theories of belief change in artificial intelligence, and to the philosophical position known as Pragmatism, proposed by Charles Peirce, to whom the term abduction owes its name.

More precisely, the book is divided into three parts: (I) Conceptual Framework, (II) Logical Foundations, and (III) Applications, each of which is briefly described in what follows.

In part I, the setting for the logical approach taken in this book is presented. One the one hand, chapter 1 offers a general overview of the logics of discovery enterprise as well as the role of logic in scientific methodology, both in philosophy of science and in the fields of artificial intelligence and cognitive science. The main argument is that logic should have a place in the normative study in the methodology of science, on a par with historical and other formal computational approaches. Chapter 2 provides an overview of research on abduction, showing that while there are general features and in most cases the main inspiration comes from the American pragmatist, Charles S. Peirce, each approach has taken a different route. To delineate our subject more precisely, and create some order, a general taxonomy for abductive reasoning is then proposed, of which a brief description is the following:

A Taxonomy for Abduction

As for the logical form of abduction it may be viewed as a threefold relation:

$$\theta, \alpha \Rightarrow \varphi$$

between an observation φ, an abduced item α, and a background theory θ. Against this background, we propose three main parameters that determine types of explanatory arguments. (i) An 'inferential parameter' ($\Rightarrow$) sets some suitable logical relationship among explananda, background theory, and explanandum. (ii) Next, 'triggers' determine what kind of abductive process is to be performed: φ may be a novel phenomenon, one which did not existed there before, but not in conflict with the theory. Alternatively, φ may be an anomalous phenomenon, one which is indeed is in conflict with the existing theory θ. (iii) Finally, 'outcomes' (α) are the various products (abductive explanations) of an abductive process: facts, rules, or even new theories.

Several forms of abduction are obtained by instantiating these three parameters: the kind of reasoning involved (e.g., deductive, statistical), the kind of observation triggering the abduction (novelty, or anomaly with respect to some background theory), and the kind of explanations produced (facts, rules, or theories). This taxonomy gives us the big and varied picture of abductive reasoning.

In part II, the logical foundations of this enterprise are laid down. In chapter 3, abduction is investigated as a notion of logical inference. It is shown that this type of reasoning can be analyzed within various kinds of logical consequence as the underlying inference, namely as classical inference (backwards deduction), statistical or as some type of non-monotonic inference. The logical properties of these various 'abductive explanatory kinds' are then investigated within the 'logical structural analysis', as proposed for non-monotonic consequence relations in artificial intelligence and dynamic styles of inference in formal semantics. As a result we can classify forms of abduction by different structural rules. A computational logic analysis of processes producing abductive inferences is then presented in chapter 4, using and extending the mathematical framework of semantic tableaux. I show how to implement various search strategies to generate various forms of abductive explanations.

Part III is a confrontation of the previous analysis and foundations with existing themes in the philosophy of science and artificial intelligence. In particular, in chapter 5, I analyze the well-known Hempelian models for scientific explanation (the deductive-nomological one, and the inductive-statistical one) as forms of abductive explanatory arguments, the ultimate products of abductive reasoning. This then provides them with a structural logical analysis in the style of chapter 3. In chapter 6, I address the question of the dynamics of empirical progress, both in theory evaluation and in theory improvement. I meet the challenge made by Theo Kuipers, namely to operationalize the task of 'instrumentalist abduction', that is, theory revision aiming at empirical progress. I offer a reformulation of Kuipers' account of empirical progress into the framework of (extended) semantic tableaux, in the style of chapter 4, and show that this is indeed an appealing method to account for empirical progress of some specific kind of empirical progress, that of lacunae.

The remaining two chapters have a common argument, namely that abduction may be viewed as a process of epistemic change for belief revision, an idea which connects naturally to the notion of abduction in the work of Charles Peirce, and that of belief revision in the work of Peter Gärdenfors, thus suggesting a direct link between philosophy and artificial intelligence. In chapter 7, I explore the connection between abduction and Pragmatism, as proposed by Peirce, showing that the former is conceived as an epistemic procedure for logical inquiry, and that it is indeed the basis for the latter, conceived as a method of philosophical reflection with the ultimate goal of generating 'clear ideas'. Moreover, I argue that abduction viewed in this way can model dynamics of belief revision in artificial intelligence. For this purpose, an extended version of the semantic tableaux of chapter 4 provides a new representation of the operations of expansion, and contraction, all of which shapes the content of chapter 8.

Questions and Challenges

Is Abduction Ignorance-Preserving?

In his contribution "Ignorance and Semantic Tableaux: Aliseda on Abduction" John Woods raises two fundamental aspects of abduction. One concerns its subjunctive character, expressed in Peirce's well-known logical formulation:

> The surprising fact, *C*, is observed.
>
> But if *A* were true, *C* would be a matter of course.
>
> Hence, there is reason to suspect that *A* is true.

The other related aspect highlights the conjectural nature of hypothesis *A*, suggesting the characterization of abduction as an ignorance-preserving inference. According to Woods, abduction is one of three possible responses to an ignorance problem, one in which one attempts to solve a target through answering a question of the type *Does such and such is the case?* The first kind of response to an ignorance problem corresponds to acquiring new knowledge in order to solve the target and perform an action; the second one corresponds to abandoning the target and leave it unsolved, without performing any further action. A third possibility is abduction, in which the target remains unsolved, but still the conjectural result is the basis for a new action. An application par excellence of this third type of response to an ignorance problem is found in the area of law, concerning criminal jurisprudence in the common law. "When jurors find an accused guilty of the offence with which he has been charged, they do not know whether in fact the offence was committed by him" (Woods, page 316, this issue).

According to this view, abduction is reasoning which fails to fully answer the ignorance problem, but offers reasons as basis for certain actions. This illustration in law is indeed strong evidence of the way humans do act in the absence of knowledge —the accused is charged and thus convicted. This kind of analysis is essential for research in practical logic for cognitive systems, the topic of concern to Woods and his collaborators.

The Choice of a Logic for Abduction

One of the key issues in any kind of conceptual analysis, is the choice of a logical framework. Different choices lead to different representations and may come from different conceptions. The approach by Woods, known as the GW model, enters in conflict with the AKM model —coined after the initials of some of its promoters, of which I am one of them. This is the logical approach aiming to characterize abduction as an inference, often expressed as deductive logical entailment, with some additional conditions. The AKM model runs in parallel with Hempel's DN-model, in the sense that it is mainly a deductive logical account in which the theory, together with the explanation (abduction) do entail the explanandum. It does not require abductive inference to be ignorance-preserving. The

AKM model is therefore consequentialist, as opposed to the one of Woods which is subjunctivist.[1]

One interesting new research question is whether the AKM model generalized as to include weaker forms of consequence relations, involving one for conjectural entailment, may allow the representation of the GW model, at least in so far the underlying inference is concerned. In fact, as acknowledged of my approach, my model of abduction allows for several forms of consequence, for I consider the logical relation between explananda and explanandum as a general parameter, as shown in my proposed taxonomy. However, I do not see how to represent the GW model in a straightforward manner. Fortunately, two of the presented contributions to this issue may shed some light to this challenge, for they attempt to model finer views of abductive inference, and go beyond my analysis on several forms of consequence and their corresponding structural rules for abduction.

In their contribution "Metamodeling Abduction", Angel Nepomuceno and Fernando Soler put forward an interesting view of abduction as a consequence relation, drawing on Makinson's bridges between classical and nonmonotonic logic; in particular using a *pivotal-assumption consequence*,[2] of which we may say that it assumes rather than affirms the premises. They propose to represent a general abductive problem in terms of an explicative relation <T, F>, one in which a fact F is explained by S (a set of solutions) with respect to a consequence modulo T (the background theory) and α (an explanation) . The following is their representation of my plain abduction (T, $\alpha \quad F$):

$$F \quad {}_{\alpha, T}\ S$$

This explicative consequence relation $\quad {}_{\alpha,\, T}$ may be characterized in terms of structural rules, just as I did for my version of consistent abduction (Aliseda 2006, *cf.* chapter 3). The authors have observed that in general, an explicative consequence of this kind, validates the structural rules corresponding to reflexivity, right cut and right monotony.

Another interesting point regarding the view of abduction as a logical inference is shown by Ilkka Niiniluoto in his contribution "Structural Rules for Abduction", in which he explores several structural rules for "backward" abductive reasoning, that is from observations to explanatory theories. One of his proposals for (partially) representing Peirce's logical formulation is as a form of *converse deductive explanation*, a notion defined by the author back in 1973:

$$e\mathrm{A}h =_{\mathrm{df}} h\mathrm{E}e.$$[3]

As it turns out, several of these attempts for characterizing consequence relations regarding inductive and abductive styles of inference, were actually proposed in the context of philosophy of science, to capture notions like inductive confirmation. These were indeed analyzed with similar forms of structural rules as those later used in artificial intelligence for the characterization of nonmonotonic logics. For example, Niiniluoto shows

[1] In my view, the AKM and the GW models are complementary. While the former focuses on the role of surprise in Peirce's formulation, the latter centers its attention on the subjunctive form of the abductive formulation.

[2] x is a consequence of A modulo K iff x is a consequence of $K \cup A$. That is, $A \quad {}_K x$ iff $K \cup A \quad x$.

[3] This says that h is abducible from e iff h deductively explains e.

that the well-known *high probability criterion of confirmation* ($e\mathrm{I}h$ iff $\mathrm{P}(h/e) > q \geq ½$) satisfies the principle of Special Consequence (SC):

(SC) If $e\mathrm{I}h$ and h g, then $e\mathrm{I}g$.[4]

This confirmation criterion is known as characteristic to "enumerative" and "eliminative" reasoning.

Thus, new explicative consequence relations may be defined by considering pivotal-assumptions —as the one presented by Nepomuceno and Soler— or even by pivotal-valuations or pivotal-rules consequences. Moreover, a variety of structural rules may be checked for satisfiability for all these kinds of consequence relations, and sets of these may characterize each one in turn. In fact, as Niiniluoto suggests, the way to go may be to combine several notions of consequence at hand, in accordance with my proposal for exploring structural rules combining deductive and inductive explanations (Aliseda 2006, chapter 5).

Perhaps in actual research on abduction we are still in the phase in which there is no single consequence capturing all aspects of abduction, but rather a set of consequence relations, each one capturing a partial picture of it. However, under my view, this situation rather reminds us that "abduction is not a new form of inference. It is rather a topic-dependant practice of explanatory reasoning, which can be supported by various notions of inference, classical or otherwise" (Aliseda 2006, p. xii). Moreover, even when the underlying inference is deductive in nature, given the additional requirements that abduction calls for, there are multiple and various ways to characterize abduction as a logical inference, and in any interesting case, the resulting inference is never fully deductive.

The Choice of Semantic Tableaux as a Logical Framework for Abduction

Another logical choice I made in the design of my abductive model was the use of semantic tableaux as the logical framework for abduction.[5] This is a refutation method, and works by attempting to construct models (counterexamples) for the premises and the negation of the conclusion. When this can be done, the resulting tableaux-tree has open branches, each one representing a verifying model. The failure of the original consequence is thus reflected by the open branches. The open tree indicates that the theory is consistent and that the theory does not entail the proposed conclusion (neither its negation). It turns out that this is precisely the precondition for abduction (the novelty kind). Thus, performing abduction comes down to closing the open branches, and this is a very intuitive and appealing way of understanding abduction. In reflecting whether the choice of tableaux was a good one, I can only repeat myself about the virtues of this logical framework:

> Semantic tableaux are a natural vehicle for implementing abduction. They allow for a clear formulation for what counts as an abductive explanation, while being flexible and suggestive as to possible modifications and extensions. Derivability and consistency, the ingredients of consistent and explanatory abduction, are indeed a natural blend in tableaux, because we can manipulate open and close branches with equal ease. (Aliseda 2006, p. 130)

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[4] This says that if h is inducible from e, and g follows from h, then g is inducible from e.

[5] The framework of Semantic Tableaux was proposed independently by Hintikka and Beth in the late fifties, and a decade later refined by Smullyan (cf. Woods contribution for a summary of my semantic abductive tableaux approach and Chapter 4 of my book for all further details).

However, there is no unique way to devise a computational procedure to produce those abductions which close the open branches. Note that just closing the open branches would produce all abductive explanations which are inconsistent with the theory, and this is of course undesirable. Therefore, a further selection process has to be performed, ideally filtering only those solutions which we really want to count as explanations, or at least, avoiding those which are inconsistent or redundant. Extended Semantic Tableaux of the kind I propose, are the logical structure over which a certain calculi with its particular heuristics is operating. The semantics, syntax, metalogic and even the structural analysis are not altogether enough to operate a logical system. There is always a need for an heuristics, for a search strategy. This is put forward by the following equation (Aliseda 2006, p. 49):

Abductive Logic = Inference + Search Strategy

Several authors in this issue have stressed the need of devising heuristics within an abductive calculi, and thus put forward the view of logic as a search control strategy. In particular, in their contribution "Abduction through Semantic Tableaux versus Abduction through Goal-Directed Proofs", Joke Meheus and Dagmar Provijn propose a calculi of such kind. According to these authors "abductive explanations are a natural spin-off of goal-directed proofs" (Meheus and Provijn, page 296, this issue), in the sense that the explanandum is the starting point of the derivation and acts as guide to the inferences drawn during the derivation. Moreover, these kind of proofs form a decision method for $A_1, \ldots, A_n$ B, and are primarily based on the analysis of formulae (*cf.* Meheus and Provijn contribution for the details).

What is clear to me is that the diversity of ways to compute abduction continues to multiply. In the case of my own proposal, I do not regard it as a final word, for some other approaches have shown that it works better when combined with other procedures, such as the one by Meheus and Provijn.[6]

Abduction as Inference to the Best Explanation

It is evident from my proposal that I do not deal with abduction as inference to the best explanation (IBE), for I do not tackle the problem of how to produce the best or minimal

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[6] I have an open discussion with Meheus and Provijn (*cf.* footnote 4 of their contribution) regarding my algorithms. I use this brief space to make a couple of remarks. The authors claim their method tackles in a more efficient and transparent way the production of good explanations, at least in so far as it gets rid of redundant, irrelevant and inconsistent ones. This seems to be the case. However, except for the inconsistencies, the production of irrelevant explanations is nevertheless produced in their calculi, though their method warrantees to mark the lines in which they appear and are thus not taken into account as responses (p. 302). However, I do not agree with their criticism on example 1, for my non-redundancy condition rules out those formulas which contain abductive explanations as subformulae (Aliseda 2006, p. 111).

Another issue I would like to point out concerns my definition of partial explanations. My intuition is right in that *partial explanations* are those formula α which effect a semi-closed extension over a tableau for the theory θ and the negation of the observation $(\neg\varphi)$. However, in the case of conjunctive explanations, in order to avoid the production of inconsistent explanations, it is needed that the proposed conjunctive explanation effects a semi-closed extension over the original tableau for the theory θ as well. Therefore, a finer definition for a partial explanation α is one in which both $T(\Theta + (\neg\varphi) + \alpha)$ and $T(\Theta + \alpha)$ are semi-closed. Given this refinement, an additional instruction may be added after instruction 6 of my algorithm (Aliseda 2006, p. 115), just as Meheus and Provijn have observed in their criticism, which I gratefully acknowledge.

abduction. Methodologically, I made a choice of splitting the problem of abduction into two processes: generation and selection.[7] This separation helps to split the logical and the empirical aspects of an abductive explanation into two. According to Niiniluoto, my approach is discussed in the weaker sense, in which abduction is reasoning from a fact to one of it potential explanations, rather than the stronger sense, in which the reasoning is to the minimal or best explanation. This is of course in line with Hempel's notion of *potential explanation*, one which complies with the logical criteria but needs a further test for truth to be assessed as an explanation.

I defend to split the generation and the selection processes of abduction for its logical analysis, but grant at the same time that a picture of abduction is incomplete when one of them is missing. Moreover, sometimes it is not evident that the same kind of abduction (and in particular, of selection) is taking place in both common sense reasoning and scientific reasoning. In his contribution "Abduction and Inference to the Best Explanation", Valeriano Iranzo makes this point arguing that while abductions performed for perceptual judgment have in general no problem in assessing quite automatically its truth-value, abduction set in the scientific context is much more sophisticated: "History of science is paved with discarded, and presumably, false theories" (Iranzo, page 342, this issue). A reliabilist justification for abduction works for the former, but not for the latter. We need a finer account of what counts as the best explanation, or as a good explanation, for that matter. There is no consensus on this matter, however, for there seems to be no best explanation of what counts as such.[8]

Regarding my own position (according to Iranzo I favor a purely heuristic approach as opposed to an epistemic one), I do endorse a heuristic approach, at least in so far my logical and computational analysis can support. I argue in my book that the selection process is beyond logical criteria, and belongs rather to a pragmatic context. This does not mean however, that I do not take an epistemological stance in regard to abduction. Indeed, I consider abduction as an epistemic process for belief change (Aliseda 2006, *cf.* chapter 8), and this is the topic of next section.

Abduction as Belief Revision

In my view, abduction is an epistemic process for belief change. The overall cognitive process is depicted as follows:

> A novel or an anomalous experience (*cf.* chapter 2) gives place to a surprising phenomenon, generating a state of doubt which breaks up a belief habit and accordingly triggers abductive reasoning. The goal of this type of reasoning is precisely to explain the surprising fact and therefore soothe the state of doubt. It is 'soothe' rather than 'destroy' for an abductive hypothesis has to be put into test and be eco-

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7 Other authors draw on this distinction. Witness Magnani's "creative vs. selective abduction". Peirce himself refers to both in connection to abduction.

8 As Iranzo points out, while Niiniluoto makes a link between explanatory value and truth by means of confirmation, Psillos favors the best explanation as the one which fits better our background beliefs, by means of the notions of acceptance and coherence. Psillos account works well for everyday reasoning and the one by Niiniluoto seems more appropriate for scientific contexts in which it comes down to selecting the explanation that best confirms the theory, with respect to the rest in stock.

> nomic, attending to the further criteria that Peirce proposed. The abductive explanation is simply a suggestion that has to be put to test before converting itself into a belief.[9] (Aliseda 2006, p. 175)

In this respect, my view seems compatible with that of Woods: "not only does abduction not secure us knowledge, it does not warrant belief" (Woods, page 315, this issue). Abduction only provides a *reason to suspect*, and this is were the conjectural aspect shows its face. This is a true claim when made over the explanatory aspect of abduction, of which Peirce's logical formulation is based. The point is that the conjectural character of abduction may be surpassed when the testability requirement is at work. However, going back to the example of criminal jurisprudence, that is a case in which all evidence is already given, and there is no possibility for further testing hypotheses at hand.[10]

Thus, the road from ignorance to knowledge is a complex one, involving several steps, and in which it is often impossible to walk it all the way through. In fact, even in a scientific context, the result of testing a hypothesis gives only an approximate truth as an outcome. In his contribution "Idealization, Abduction, and Progressive Scientific Change", Xavier de Donato links abduction to two key notions in scientific change, namely *idealization* and *concretization*, and presents them as the very essence of the scientific method.[11] For him, "to abduce the best explanation becomes in the present context to find the best concretized form of a certain law, which is proved to be approximately true" (de Donato, page 336, this issue). In fact, although it is in principle impossible to test idealizations —given that their ideal conditions are never realizable— the way of testing them is by an approximation to the limit value, proving that the idealized law approximately holds. An example of an intertheoretical relation of this kind is the Kepler-Newton case (Kepler's laws of planetary notion vs. Newtonian celestial mechanics), in which "Newton accepted Kepler's laws as empirical generalizations holding only approximately and arrived at his theory in part trying to give a theoretical explanation for these laws" (de Donato, page 336, this issue).

The link to my abductive proposal is straightforward, for the logic of idealization is based on Gärdenfors belief revision model, in particular applied to the account of counterfactual suppositions, those that effect the belief change over the theory. Moreover, this view is also directly linked to my abductive semantic tableaux model when applied to Kuipers' notion of *instrumentalist abduction*, theory revision aiming at empirical progress (Aliseda 2006, cf. chapter 6). One final thing to point out on the challenge made by de Donato,

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[9] For Peirce, three aspects determine whether a hypothesis is promising: it must be *explanatory*, *testable*, and *economic*. A hypothesis is an explanation if it accounts for the facts. Its status is that of a suggestion until it is verified, which explains the need for the testability criterion. Finally, the motivation for the economic criterion is twofold: a response to the practical problem of having innumerable explanatory hypotheses to test, as well as the need for a criterion to select the best explanation amongst the testable ones.

[10] Woods is right in highlighting the conjectural character of abduction, something that is often overseen and it is certainly a misrepresented aspect of abduction, and makes perfectly good sense in the cases where testing is impossible. Another area in which this is the case concerns historiography, in which the historical hypotheses cannot be tested against a past that is already behind.

[11] The idealization-concretization process goes from idealizations —which involves model construction and the assumption of certain counterfactual conditions in order to derive laws from theories— to the concretizations of theories considered to be approximately true.

namely to apply my abductive tableaux model, is that we would have an opportunity to test real life scientific cases. I am particularly interested in those cases involving anomalies, and in this respect semantic tableaux are once more, a natural vehicle to represent theory revision for anomalous cases.

Moreover, when a view of science as problem solving is endorsed —such as the one by Popper and Simon (Aliseda 2006, *cf.* chapter 1)— together with my view of abduction as an epistemic process for belief change, the dichotomy of contexts of discovery vs. justification is doomed to fail. This is precisely issue raised by Ana Rosa Pérez Ransanz in her contribution "¿Qué Queda de la Distinción entre Contexto de Descubrimiento y Contexto de Justificación?":[12]

> Abduction [understood as a process of epistemic change] allows to integrate in a natural way, both processes of ideas generation and evaluation (using Aliseda's terminology), something which makes even more evident the artificial character of the old discovery-justification dichotomy. (Pérez-Ransanz, page 350, this issue)

Are Abductive Tableaux in Our Heads?

The tableaux representation together with its machinery for computing abductions is suggestive as a psychological model and raises a new challenge —which goes beyond the conceptual analysis done in my book— namely whether these tree tableaux structures are plausible as a model of the mind for performing abduction. This issue is raised by Sílvio Pinto in his contribution "Dos Aspectos del Razonamiento Abductivo".[13] According to him:

> An answer to this question would have to appeal to the psychological evidence for or against the proposal of abductive semantic tableaux and, in a larger frame, it would depend on the greater or smaller plausibility of the so called computational model of the mind. (Pinto, page 322, this issue)

However, for Pinto, there is still and alternative answer for the causal effectiveness of intentional mental processes, like the one determined by the semantic contents of the mental states involved in the cognitive human processes (*cf.* Pinto's contribution for the full discussion). This is an answer of a non-computational kind and rather based on the concept of *radical interpretation*, a core notion in contemporary analytic philosophy, which basically states that the semantic content of a certain language L results from the interpretation process of speakers of language L, given their behaviour (linguistic and otherwise) as evidence. For Pinto this "is an alternative explanation of the determination of causal regularities in the mental processes, given by the semantic content of their respective representations" (Pinto, page 323, this issue). Another contribution equally concerned with real life plausibility of logical models for human beings performing abduction, is the one by Lorenzo Magnani "Logic and Abduction: Cognitive Externalizations in Demonstrative Environments." Magnani responds to this challenge with a distributed cognition approach, concerning "the role of logical models as forms of cognitive externalizations preexistent in-formal human reasoning performances" (Magnani, page 275, this issue). For

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[12] "What Remains of the Context of Discovery vs. Context of Justification Distinction?" The quote to her contribution is my translation.

[13] "Two Aspects of Abductive Reasoning". The quotes to his contribution are my translations.

him, human beings spontaneously perform hasty generalization and abductive diagnoses, and this type of low-level in-formal inferential performances are part of the kit for human survival (*cf.* Magnani's contribution for further details). Woods and Gabbay also highlight the role of logic for basic human behavior: "It is that the reasoning actually performed by individual agents is sufficiently reliable not to kill them" (quoted in Magnani, page 282, this issue). So, we are after all, logical animals, as Peirce himself stated in his famous "*The Fixation of Belief*." Johan's van Benthem provoking assertion seems also appropriate: "Logic is the Immune System of the Mind" (van Benthem, page 273, this issue). A natural step in this direction would be to promote research on psychological abduction, and team up with cognitive psychologists to learn from their empirical research. There are already several competing theories of the mind with regard to human abductive performance. As shown, the traditions of Logic, Analytic Philosophy and Cognitive Science, have each one offered an alternative answer.

Conclusion

I give no conclusion for this pot of challenges ahead for abduction, offered by the thought provoking, critical and challenging contributions. They opened an agenda of new research on abduction, showing the discussion still continues. I would like to express my gratitude to all contributors to this issue and to Johan van Benthem for agreeing to write the presentation to this forum. I am also grateful to Andoni Ibarra, main editor of this Journal, for his invitation and encouragement to prepare this issue. I hope the reader will find something interesting and useful in the papers to follow.

Let me close by paraphrasing John Woods on the status of research of abduction:

> Abductive logic is still a work in progress. There is, as of yet, no wholly dominant view of it. The time may come when a consensus builds around a given model. When that happens, it is quite possible that it will be yet another approach. But it is entirely clear that such consensus can only arise out of the continuing efforts of the leading stakeholders to deepen, extend and generalize upon their own efforts to date. (Personal communication, 2005)

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