# Contextual Problem Solving and Adaptive Logics In Creative Processes*

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**Abstract**

Creativity is commonly seen as beyond the scope of rationality. In the present paper, it is argued that available insights in epistemology and available results in logic enable us to incorporate creativity within an independently sensible view on human rationality.

## 1 The Problem

Creativity is a typically Western notion. Its popular conception has an amazing history (someone should study this). The conception oscillates between the romantic and the rule governed view, but even where the latter prevails, a romantic overtone lingers. The capacity to be creative is typically human. It is one of these features by which humans transcend themselves. Many people seem to feel that methodological approaches degrade it. They think that creativity cannot be caught in rules, and hence cannot be fully understood. On the Western view, creativity is a paradoxical notion, very much so like (personal) freedom.

As is shown in [25], Mach, Duhem and Poincaré displayed a deep interest in the methodological aspects of creativity and wrote fascinating pages about them. Nevertheless, they consider creativity as methodologically irrelevant: the quality of a scientific theory is fully independent of its generation. After them, the superficial version of their views became the philosophical orthodoxy. Creativity was seen as devoid of methodological aspects, and hence as irrational. For decades, it was not a methodological topic. In as far as it was still paradoxical, the paradox was removed from the agenda of epistemology and even philosophy.

The reaction came in the late seventies only, and crystallized in [35] and [36]. Ever since, there is a new methodological optimism about creativity. But the 'friends of discovery', as Tom Nickles chastely calls them, are not free of paradox. Nickles's struggle with the Meno paradox illustrates this abundantly.

I suggest that the paradoxical character of the notion of creativity does not derive from this notion itself, but from the paradoxical character of Western anthropology. The latter is largely caused by a misconception of rationality

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(and hence problem-solving and methodology) and of logic. I cannot discuss western anthropology in the present paper, but I shall try to clarify some points on rationality and on logic.

## 2 Introductory Remarks

The views defended in the present paper grew out of the interaction of my work in epistemology and in logic. Where my epistemological views have developed gradually, my views on logic were drastically influenced by the discovery (in the late seventies) of (what I now call) adaptive logics. The original source of inspiration (or rather the task inflicted on me by an informal research group) was to put hands on dialectical mechanisms in logic. Trying to bring this down to matters I could understand, I started thinking about unexpected contradictions that sometimes arise in mathematical theories—typically, the Russell paradox—and about their elimination. Thus, the basic exemplar was a discovery process urged by an inconsistency. When I became acquainted with Tom Nickles's work, I realized its novelty and importance. Moreover, it was obvious at once that this work fitted nicely within my epistemological views and that the adaptive logic machinery provided the means for an exact and formal account of some typically creative reasoning processes.

A few later papers on discovery seduced Joke Meheus, then a student (with a long standing interest and experience in musical creativity), to work with me on discovery and creativity. The quality of her work led to a Ph.D. and an academic career, and to some hard and fascinating challenges for me. I owe much to Joke Meheus's work on creativity and discovery—see her paper in the present volume and, *e.g.,* [27], [26], [28], and [30]. Where I had some ideas, she worked on a theory. The results of her work changed my views, as one might expect. Much of what is said below derives directly from her views—spelling this out everywhere would be too tiresome.

Creative processes display some distinctive features with respect to other problem solving processes. *Epistemologically interesting* discoveries always result from creative processes, but some discoveries are accidental,[1] just as some creative problem solving processes are unsuccessful. I now describe those distinctive features of creative processes in terms of constraints.

*One.* Constraints are *specific* for a problem. This means that not all of our knowledge (not our whole knowledge system) is relevant for a particular problem. More specifically, many problems are solved *within* a definite theory. There is more to this, and it is nicely illustrated by the fact that some knowledge elements may prevent the solution of the problem, even if the means to solve the problem are available within the knowledge system. The cause is obvious but often overlooked. One may question a conviction, or even explicitly reject it with respect to some questions, but continue to use it to tackle (other) problems. Easy examples are the continuous use of Newtonian physics in this relativistic era, and the many rules that engineers apply while knowing 'in a different context' that they are incorrect. A different way to make the point is by saying that problem solving evolves with respect to background knowledge—a poor term for constraints—but that the background knowledge for a particular

[1] Beware: even these require competence and attentiveness on the part of the discoverer—the solution should be recognized.

problem does not encompass our whole knowledge, and sometimes even conflicts with parts of our knowledge system.

*Two.* Constraints change during the problem solving process. Some may be modified, some dropped, some added. This is obvious as far as empirical data are concerned, as the process may lead to new observations and experiments. But it also holds for other constraints: lawlike and theoretical elements, heuristics, and even the conceptual framework. The chief reason for this feature is that, in the interesting cases, the original constraints do not allow one to solve the problem. The insights and actions provoked by the problem solving process itself cause modifications to the constraints and hence sometimes also to the problem. Tom Nickles noted this a long time ago, and spelled out the ensuing paradox—see already [34] and [33].

*Three.* A solution of a problem may proceed in terms of the 'personal' constraints of an individual or research community. Although these may not be shared by larger communities, the solution may be (or become) acceptable to the latter—see [31].

*Four.* Sometimes, the constraints are inconsistent—arguments may be found in [21], [26], [30], and many other places. Non-logicians, once convinced of the phenomenon, often underestimate the resulting difficulties. For one thing, the inconsistency is nearly never resolved by just dropping some constraints. As the problem solving process proceeds, new insights are gained from the *reasoning* involved. As a direct or indirect result of these insights, some constraints are refined: restricted or otherwise modified. From a logical point of view, the effect of a set of constraints should be identified with its deductive closure (all consequences derivable from it). It follows at once that classical logic (henceforth **CL**) is unfit for handling inconsistent situations: it equates the deductive closure with the set of all sentences—logicians call this the trivial set.

Some will argue that our actual reasoning proceeds in terms of sets of premises, not in terms of their deductive closures. The point is somewhat subtle. In view of the human brain capacity, they are quite right (provided they don't mean "independent axioms"). However, this does not in any way lessen the problem. From a set of statements, for example a set of constraints, we may derive a finite number of consequences by means of rather simple deduction rules. But it is easily shown that, if the set is inconsistent and **CL** is applied, a few steps are sufficient to arrive at consequences that are absolutely inappropriate from a problem solving point of view. So, the problem is an acute one, and by no means easier to solve than the problem that originates in connection with the deductive closure of the premises.

*Five.* In the presence of inconsistent constraints, the problem solving process requires that the inconsistencies be traced. Sometimes, the underlying, 'deeper' inconsistencies need to be identified. Next, the inconsistencies must be stepwise eliminated. Only by proceeding thus, one reaches a consistent set of constraints and a consistent solution of the problem. In general, one first resolves the low level inconsistencies (those close to the observational data). Next, this result is relied upon to move to higher (more 'theoretical') levels: one builds up towards the solution of the problem by systematizing and by resolving further inconsistencies. This move by no means reduces to an inductive procedure, but involves reliance on principles and sometimes the introduction of new ones.[2]

[2]In the case discussed in [26], Clausius almost copies a *Reductio* argument from a text of

The above features of interesting problem solving processes cannot be understood in terms of traditional means. The traditional model of rationality relies on absolute justification, and presupposes that the knowledge system is monolithic and ordered hierarchically. This directly conflicts with the first feature. Moreover, no one ever showed that the second feature may be understood (or even coherently described) in terms of the traditional model of rationality. The third feature is completely beyond the reach of the traditional model. The fourth and fifth feature rule out the use of **CL** in interesting problem solving processes that involve inconsistent constraints.

Incidentally, the traditional model of rationality and **CL** are not independent of one another. The existence of a True Logic is a prerequisite for the feasibility of the traditional model. The popular view that **CL** is the True Logic is largely due to the prevalence, in the late nineteenth and early twentieth century, of the positivistic version of the traditional model of rationality.

In the sequel of this paper I first discuss contextual problem solving, the non-hierarchical structure of our knowledge system, and the related concept of rationality. In the second half of the paper, I discuss the use of adaptive logics for understanding problem solving processes. I shall refer to inconsistent constraints, but also to more general situations. In the final section, I recall the reader how it all relates.

# 3 Contextual Problem Solving and Knowledge Systems

My views on problem solving and rationality are explained in [8]; bits and pieces in English may be found in [1], [3], [7], and [31]. In the present paper, I merely sketch the aspects relevant to the points under discussion. The reader should realize, however, that an appreciation of the arguments cannot be separated from the broader theory that incorporates those aspects.

I claim that the proposal summarized below is *realistic*. By this I do not mean that it describes the way in which humans proceed. I mean it to be realistic in a normative sense: given the kind of beings humans are, it is epistemically desirable that they proceed in this way. By doing so, they maximally increase the chances to arrive at an improvement of their knowledge (in the broadest sense of the term, including values and norms). Many philosophers have outlined systems that are more attractive in that they lead to better knowledge or lead to it more quickly. These systems, however, are not realistic in that some of their presuppositions on humans are false.

By a context I mean a problem solving situation. A context has five elements[3]: (i) the problem, (ii) contextual certainties (that determine the meaning of the problem), (iii) relevant statements (from which the solution should be obtained), (iv) methodological instructions (does and don'ts to proceed towards

Carnot's. But as one half of the inconsistency derived by Carnot is not any more available, Clausius looks for and finds another inconsistency, thus arriving at a new principle: that heat does not move spontaneously from a cold to a hot source. In the second edition of his paper, Clausius adds a footnote, not in justification of the principle, but merely in order to stress its importance—it is indeed the first sensible statement of the entropy principle.

[3]The elements are not independent of each other—see [7].

the solution), and (v) the participants[4] in the problem solving process.

"Problem" should be taken in its narrow sense here. It is the *specific* goal to be attained.[5] The interpretation of the problem is determined by elements (ii)–(iv). (ii) determines the logical space, (iv) the way in which the problem should be tackled, (iii) the means by which it should be tackled as well as the adequacy conditions on possible solutions. The elements (ii)–(iv) differ from each other as to their *function*, but all form constraints of the problem in Nickles's sense—see the papers cited earlier as well as [32].

Let me briefly summarize these functions (some applications to historical examples are listed in [31]). *Certainties* typically are not questioned *within* the context: they are considered as (contextually) *necessarily true*. In this sense they limit the *possible* solutions of the problem. They moreover partly determine the set of justified operations, and hence the "underlying logic" of the given context[6] (which need not be a deductive system and moreover may incorporate inference rules for non-verbal elements such as diagrams). The function of *relevant statements* is quite different. They do not determine the possible solutions to a problem, but impose conditions on the correct solution. They may allow us, in view of the certainties, to derive the correct solution (the correct answer to an intellectual problem), or at least to eliminate some possible solutions (as the correct solution should be compatible with them). *Methodological instructions* specify the operations we should or should not perform in order to reach the solution or come closer to it. Sometimes they form an explicit recipe for solving the problem. Often they are weaker and merely guide the problem solving process. Means-end-analysis (and similar 'general heuristics') form typical examples. In general, methodological instructions help to determine the moves the problem solver will perform within the context.

It is important to realize that the context-elements may vary from one context to the other. Not only may the constraints from one context be absent in another one, and may the same items of information fulfill different functions in different contexts, but constraints from different contexts may flatly contradict each other. This is an important and often misunderstood feature to which I return in the next section.

If a given context does not allow for the solution of its problem,[7] the problem solver (unless when he, she, or it gives up the problem) will move on to a different context in order to tackle a derived problem. The latter might be: Which elements of the original context are responsible for the failure? Which of those elements may be justifiedly modified (extended or replaced) in such a way that the problem (or a larger portion of it) becomes solvable? ... A derived problem may also concern a single element from the original context: Is it justified? Sufficiently specific? Sufficiently precise? ... In general, the process connected

[4] One should distinguish between the context for the group (that surfaces for example in the communication between the participants) and the contexts for the separate participants—all these contexts may be quite different from each other, even in the case of heavy and efficient cooperation.

[5] Solving a 'problem' in the broad sense will almost always require that a plurality of problems (subproblems, related and derived problems) are considered, and hence that the problem solving path contains a plurality of contexts.

[6] See [3] for an argument that contextual certainties cannot sensibly be distinguished from contextual logical truths.

[7] That a problem is not well defined may be taken to mean precisely this—see [31] for some remarks on this complex concept.

with a non-trivial problem proceeds through a chain of contexts concerning the (changing) problem itself, where the transition from one link to the other may be both understood and justified by a chain of contexts concerning one or more derived problems.

I should warn the reader that the above description might be misleading in that it concerns only conscious decisions. It is important to realize that a large portion of any problem solving process depends on unconscious mechanisms. I refer to [3], [8], and [7] for a more detailed treatment of this. Let me merely point out here that most contexts are 'set up' in an unconscious way. How a context is set up depends on the knowledge elements that are present in the knowledge system of the problem solver and that are explicitly *linked* to the problem or type of problem (and the problem solver need not be aware of this). As a result, a person's knowledge system may contain relevant information for the solution of a problem, but this information need not show up in the context in which this person tries to solve the problem. This explains, for example, why some people are much more able problem solvers than others, even if the relevant knowledge is available to all of them. And it obviously explains why people are better problem solvers in domains in which they exercised their problem solving skills: the right links are present in their knowledge system.

As one might expect, a knowledge system, even of an individual, is not a monolithic entity. It contains elements and subsystems each of which is 'indexed' by its function with respect to one or more problems or types of problems. These elements and subsystems need not be compatible with each other. They need not even be deductively linked to each other. And, obviously, a knowledge system is not deductively closed—see [7] for details. The traditional view gets things wrong in two respects. It first of all forgets about the 'indices' (links). As a result, it implicitly accepts that, when a problem solver (individual or group) tackles a problem, all information relevant to the problem is automatically available. Moreover, the traditional view presupposes general deductive connections, whereas the deductive connections present in real life knowledge systems are rather restricted, mainly to the more or less coherent subsystems. As a result—see also the previous paragraph—the traditional view misconstrues the *actual* problem solving behaviour of individuals and groups, and hence renders it mysterious.

That the traditional view is mistaken in constructing knowledge systems, and hence knowledge and belief themselves, as one-dimensional, is one of the central claims of the first half of the present paper. As the traditional view is widespread, and in view of the importance of its mistake, especially (but not only) with respect to creativity, I shall devote most of the subsequent section to clarify this point.

# 4 A Plurality of Contexts

Consider a sentence that functions in some context as a relevant statement. The meaning of the sentence is determined by the contextual certainties and hence may differ drastically from the meaning of the same sentence within a different context. Many readers will think to meet a familiar distinction here, viz. the distinction between a sentence and a proposition (the sentence's meaning as determined by the context). However, there is a grave danger of confusion here.

The distinction itself is quite all right, the danger lies in the way in which the relation between propositions is understood.

Once propositions are introduced, the standard move is to consider them as forming the elements of a singular system (perhaps even a calculus). Let me spell out clearly what the problem is. Sentences have context-dependent meanings[8] and hence are not stable with respect to their meanings. For one thing, if we consider only the form of sentences (of a natural language), we are unable to select any logical forms that warrant deductive correctness. This is why formal logic usually refers to 'propositions', that is: to the meanings these sentences have in a specific context. If we forget for a moment about vague or ambiguous meanings (in principle a context might rule those out), we reached a level of stability: by virtue of its definition, a proposition is not changed by moving it to a different context. Up to this point, I go along.[9] My quarrel is with the idea that all those propositions form a single system.

The classical approach to logic is largely responsible for the mistake. There is absolutely no problem with a sentential logic if the sentences belong to a *formal language*. These sentences were supposed to have a stable meaning (as is clear from all the old papers). Propositions were introduced in order to apply the results of formal logic to *natural languages*. The underlying idea was that propositions may be negated, and may be combined by conjunction, disjunction, and the other binary connectives. Nothing seems more obvious. For any proposition $p$, there seems to be the proposition that means exactly the opposite of $p$, viz. $\sim p$; for any two propositions $p$ and $q$, there is a proposition that means exactly the conjunction, viz. $p \wedge q$, etc. Applying such moves to natural languages, we readily arrive at the 'obvious' idea that all propositions expressible by natural language sentences within a context, form a single system.

My claim, as might be expected, is that all those propositions cannot be joined together into a single system. To clarify this, I am forced to refer to some technical stuff again. First, the syntactic rules of English apparently classify a denumerable set of sentences as well-formed, and each of them corresponds (in principle) to an infinity of propositions determined by the context in which the sentence is uttered. Next, consider the negation of a sentence, the conjunction of two sentences, etc. Apparently, there are contexts in which a complex sentence of this sort makes sense. Open the book Genesis, and read: "God saw that it was good." Next open Russell's "A free man's worship" and read: "United with his fellow men by the strongest of all ties, the tie of a common doom, the free man finds that a new vision is with him always, shedding over every daily task the light of love." Next consider the conjunction of both sentences. I am sure that you are, if you deploy some fantasy, able to assign a meaning to this sentence.

However, now go back to the bible, and decipher the proposition behind the sentence. Next, do the same for the quotation from Russell. And then try to consider the conjunction of both propositions. Of course, you fail to do so. Obviously, the presuppositions of both propositions conflict with each other (as in the conjunction of the proposition that the present king of Baluba is bald and the proposition that Baluba is presently a republic). I shall not discuss that point here, but merely remark that the two propositions belong to a different

[8] Any of the usual senses of "context" will do here.

[9] There is, however, a slight complication: as follows from the subsequent passage in the text, a proposition cannot be moved to any context.

conceptual frame and hence are incompatible.

Any child can provide examples to the same effect from the history of the sciences. I must, alas, open a parenthesis at this point. Confronting some fellow philosophers with the propositions intended by Carnot and propositions intended by Clausius (or Gibbs) in thermodynamics, I received knocking down reactions of the following kind: "That Carnot had a wrong view on heat did not affect the meaning (and truth or falsehood) of his statements on heat". But this is absurd. If the proposition determined by a sentence-in-context is independent of the speaker's intention and understanding, nobody has any idea of the meaning of an utterance made by him or her. If logic is about such propositions, it is totally useless to humans. Indeed, if, confronted with a set of sentences, we are unable to determine the propositions involved, then, as logic concerns relations between propositions, we are unable to find out what these relations are (what follows from the set of sentences, what is compatible with it, ...).

The point I am trying to make is that meanings of sentences may belong to different conceptual systems. If they do, it still is simple enough to connect them by means of logical constants. To do so, however, does not make sense. For more elaborate arguments on this position, I refer the interested reader to [16, §3].

Now I come to my second, and more important point. Humans are capable of thinking in different conceptual systems. They are able to jump from one scheme to the other, even if the schemes are not compatible with each other. They are capable of doing so, and they do so spontaneously. But there is more. Their beliefs may belong to different conceptual systems. In a sense, this should be absolutely obvious to anyone who consciously observed his own thinking and thought about his own views. That so few people find it obvious is largely do to the popularity of the traditional epistemological views.

Allow me to mention some simple examples. That we are able to define 100 centigrade as the boiling point of water (under normal atmospheric pressure) does not prevent us to employ a thermometer in experimentally showing that water (under normal atmospheric pressure) boils at 100 centigrade. Even if you are by no means sympathetic to the constructivist enterprise, it is fairly easy (after some exercise) to figure out that some line of argument is acceptable from a constructivist point of view, whereas some other line of argument is not. And obviously, humans, are able to solve problems within a conceptual system that is not (one of) their own.

Does this also hold for beliefs? Allow me to mention a common-sense example. A former colleague of mine was trained for eight years as a Jesuit father, but then lost his faith in the existence of God. He told me that, for several years, he had the following confusing experience. When he was at the university, he acted and thought as an atheist. However, when he was with his (deeply christian) parents in his home village, he acted and thought as a christian. Any of us are able to find a situation that is perhaps less dramatic but nevertheless similar. It would be a mistake to consider this point as merely sociological. It is correct that sociological factors influence our way of thinking, but it is much more impressive that the human mind is actually capable of such adaptation. A slight shift in 'context' is able to move us from one conceptual scheme to the other.

Let me give an example that is not related to sociological influences. We

all have a set of firm beliefs, for example in some scientific domains. But at the same time, we realize (if we are sensible) that our views may be mistaken and probably are mistaken in many respects.[10] This does not mean that we do not really hold the former beliefs. For example, in order to organize their lives in a meaningful way, sensible people have a worldview (a view on themselves, on their place in the universe and in humanity, ...). If anything is believed in a serious way, a worldview is. But this does not prevent one to realize that this worldview is hypothetical and tentative, that it may later be modified, that future information and insights may prove it mistaken.

There is nothing much special about this situation. A worldview is related to a specific set of problems. Whether our worldview is fallible is a problem that does not itself belong to that set. And it is a fact, as well as efficient, that humans do not simply have beliefs, but that they have beliefs *with respect to* specific problems.[11] Of course, this is not an excuse for incoherence. Similar problems should have similar answers. If they have not, they are in need of a justification (which should show the problems to be different after all).

The last example is a rather extreme one. Few people will deny that one may (and should) consider one's convictions as fallible. The fallibility of theories is an attainment in the sciences since the nineteenth century. Fallibility of knowledge in general separates the free thinking tradition (and its *liber examinatio*) from the dogmatic one. However, I would like to defend the idea of 'believing with respect to a problem'—let us call it 'contextual belief'—in a much more general setting. My claim is that contextual belief is the *rule*: all human belief is originally contextual. Obviously, some incoherence is likely to result. If it does, and if the matter is important, sensible people try to remove the incoherence. However, (i) the incoherence cannot always be removed and (ii) sometimes it better is not removed. Claim (i) obviously refers to examples as the above. Claim (ii) refers to tinkering, to playing with ideas, to the flexibility of the human mind.

This flexibility is typical for human problem solving in general and for human creativity in particular. This flexibility is not merely that humans are able to convey quite different meanings by means of the same sentence[12], but rather that they are able to jump to different conceptual frames (in which "heat" may denote a substance, an atomic movement, or just a whatever-it-is phenomenon). *This* ability is a prerequisite for human creativity: we may (in as far as our contemporary capacities allow) add or (more frequently) remove meaning elements for a specific term, and reason from whatever remains.

It is absolutely obvious how this flexibility may be understood within a contextual approach to problem solving. Views that consider natural languages, knowledge systems, and belief systems as monolithic break down at this point. At their best, they allow for the contraction and expansion of knowledge systems—see *e.g.,* [24]. This is much too weak to even understand how people with opposing view might discuss with each other (see [3, §3]). A plurality of contexts and the flexibility of human reasoning is completely beyond its scope.

[10] A little knowledge of the history of the sciences is sufficient to convince us of this.

[11] So, the 'paradox of the preface' is simply not a paradox.

[12] Even a clearcut 'signaling language' (*cf.* Cassirer) as the one used by bees, allows these insects to convey by the same signals the location of (in a 'normal' situation) an attractive source of nectar as well as the location of (in a swarming situation) an attractive nesting place.

## 5 Rationality

In our days, it is rather fashionable to argue against foundational and absolute forms of rationality, and in favour of a 'relative' rationality—relative to the historical period and the insights available in it.[13] As appears from my treatment of meaning, I think this 'relativity' should be pushed further. Rationality refers to a justification that depends on the insights of a problem solver (individual or group) with respect to a specific problem. That a problem solver relies on private convictions to solve a problem, does by no means make the solution irrational. A different question is whether and why the solution will be accepted by a larger community, and the contextual approach offers a decent means to handle this question—see [31].

A theory about relative rationality is rather pointless if it does not contain a problem solving model and a view on meaning. I have summarized some points in the previous sections and referred to further materials there.

Moreover, a theory about relative rationality should incorporate a view on logic. Quite obviously, the traditional view on logic is a very narrow one. Combined with **CL**, it is bound to push any sensible approach to creativity outside the domain of rationality. In the two subsequent sections, I present two brief (and rather independent) comments on logic. First, I attack a central tenet of the traditional view on logic. This is rather important, as many adherents of recent research programmes in logic still adhere to that view. Next, I shall briefly outline a type of logics that are particularly fit for creative problem solving processes.

## 6 On Logic and Logic

The traditional view on logic clearly separates the realm of logic from that of actual reasoning. The former proceeds in some formal language of the traditional kind: every constant has its stable, unambiguous and exact meaning. The latter proceeds in natural language: meanings are ambiguous, vague, and unstable: different occurrences of the same 'constant' may have different meanings that are determined by the context. The gap is supposedly bridged by the 'formalization' of natural language reasoning. This operation is considered as extra-logical or pre-logical, and hence is pushed outside the realm of logic.

The basic weakness of this account of logic is the difficulty to justify the claims on logical truth (correctness, etc.). If Logic pertains to the Heaven of Purity, how can we humans, living in the dirt of everyday decision making, ever have access to Logic? Let me put this in different words. We may all construct our own logical heaven—it be classical, intuitionistic, relevant, dialetheic, or whatever. And we may all formalize pieces of actual reasoning in such a way that the result fits our logical heaven, and hence may be judged correct or incorrect. But there is no way to decide whether any of these logical heavens is the true one.[14] And, given this, there is no way to decide whether the pieces of actual reasoning are correct or incorrect.

[13] Needless to say, relative rationalists oppose relativism, post-modernism, and other forms of irrationality.

[14] There still is the possibility that logical heaven does not exist. In that case, logic, thus conceived, is about nothing.

The situation is largely similar to that in ethics. Some moral theologians from catholic universities claim that the Ten Commandments are the True Moral Rules, but that we often should transgress them, thus opting for the Lesser Evil (in this imperfect world). The weakness of their position is that there is no way to know which rules or values are adequate in the morally 'ideal world'. All experience available to us, humans derives from the present morally imperfect world.[15]

The preceding criticism of 'formal logic' should not be conceived as a plea for an 'empirical' logic. The last fifty years have witnessed many attempts to approach reasoning from the 'empirical' side (argumentation, natural reasoning, informal reasoning, ...). All of them were, to put it bluntly, vague, messy, and notoriously ineffective. This, however, should not prevent logicians from making the opposite move. This move starts from the safe paths of logical scrutiny and slowly removes the restrictions imposed by classical requirements (often prejudices). Needless to say, each relaxation should be accompanied by a careful metatheoretic study: What is still under control? How do semantic insights relate to proof theoretic features? How about decidability? How about positive tests? How about positive criteria? ... The study of adaptive logics has followed precisely this road. This, and the intrinsic relevance of these logics to the problem of creativity, makes them worth being considered in the present context.

# 7 Adaptive Logics

In many situations, solutions to problems are arrived at by means of reasoning. If one takes a closer look at this reasoning, one readily finds out that (whatever conventions on the 'formalization' of the arguments) there is no way to understand it in terms of **CL** or in terms of other alternative logics (intuitionistic, relevant, dialetheic, ...). A specific problem (about inconsistency) led to adaptive logics. Later, new types of problems were found to be within reach, and the programme was gradually broadened. By now, the adaptive programme has provided a large set of means to build formal-logical systems that are much closer to actual reasoning. One way to describe the situation, is that, working upwards from a strictly formal position, we are able to integrate several typical aspects of 'argumentation': (proof theoretic as well as semantic accounts of) dynamic reasoning, meaning variance (of logical as well as non-logical constants), inferential information (as opposed to omniscience), and languages that are not compounded by pre-fixed building blocks—see especially [11] and [10]. The central feature, as will be clear to the reader, is that adaptive logics capture dynamic aspects that are so typical for actual reasoning. The dynamics of the proofs relates to the fact that adaptive logics do *not*, as usual non-standard logics, *invalidate* certain rules of inference, but *restrict* their applications to consequences of the premises that fulfill certain conditions.

I shall start by explaining the notion of an inconsistency-adaptive logic, then move to abnormality-adaptive logics in general, and finally consider the even more general notion of an adaptive logic.

[15] Today, catholic theologians are reluctant to invoke God's Word. Precisely this makes the comparison sensible—three centuries ago, logicians gave up a similar type of authority.

Inconsistency-adaptive logics originated from the aim to interpret as consistently as possible a theory that was intended as consistent but turned out to be inconsistent. The first formulation of inconsistency-adaptive logics was proof theoretical—see, *e.g.*, [6] and [2]. The idea was to reason from a set of premises, presupposing consistency until inconsistencies appeared in a proof. If inconsistencies surface in the proof, the idea was *not* to move down from **CL** to some paraconsistent logic, but to restrict the **CL**-rules only in connection with the *specific* inconsistencies that had been derived from the premises. This proof theory is *dynamic* in that the derivation of an inconsistency (or of a disjunction of inconsistencies) may force one to revise earlier derivations. For example, the derivation of $q$ from $\sim p$ and $p \vee q$ presupposes the consistent behaviour of $p$: if both $p$ and $\sim p$ are derivable from the premises, $p \vee q$ is an obvious consequence of $p$ and the premises do not warrant $q$. So, if $q$ is derived from $\sim p$ and $p \vee q$ at some stage of the proof in view of the presupposed consistent behaviour of $p$, and $p$ is derived at a later stage, $q$ has to be considered as not derivable any more at that stage.

Given the novel nature of dynamic proofs, they justly aroused suspicion. For one thing, one should be able to show that such proofs lead to a correct outcome in the long run. This is why 'derivability at a stage' is opposed to 'final derivability'. The latter is defined with respect to dynamic proofs, and it is moreover defined in terms of a monotonic paraconsistent logic. It is moreover proved adequate with respect to a semantics—see [4], [13], and other papers.

Final derivability offers us the required interpretation (as consistently as possible) of the possibly inconsistent premises. The characterization of the final consequence set of $\Gamma$ in terms of the paraconsistent logic provides a correct definition, but not a means to find out what is finally derivable from $\Gamma$. Similarly for the semantic characterization. This holds especially as derivability in paraconsistent logics and in the adaptive logics based on them, is undecidable, just as in **CL**. Here the use of the dynamic proofs appears: they offer a means to find out what is finally derivable from the premises, even if the insights gained are provisional. They allow us to reason about $\Gamma$. Moreover, the dynamics of this reasoning is very close to the dynamics that we all know from real life reasoning, whether on everyday matters or in the sciences. If we discover that one of our theories is inconsistent, we do not simply give it up. We rather reason from it in order to replace it by a consistent improvement. We apply our logic unrestrictedly to consequences of the theory if we suppose these consequences to be consistent. And we proceed more carefully if such consequences are known to be inconsistent in order to avoid triviality. In such environments, we do not derive a consequence if *anything* may be derived by the same reasoning.

As one might expect, inconsistency-adaptive logics are in a worse situation than **CL** with respect to decidability. Where both are undecidable (at the predicative level), there even is not a positive test for derivability in most inconsistency-adaptive logics.[16] However, there are certain *criteria* that tell us, in specific cases, that a wff derived in a proof from $\Gamma$ is finally derivable from $\Gamma$.[17]

The lack of a positive test is matched by a positive feature of dynamic

[16] The propositional fragments are just as decidable as that of **CL**.

[17] Obviously, this is not a good reason to loose interest in adaptive logics. After discovering that predicate logic is undecidable, no logician was stupid enough to give up the study of predicate logic.

proofs. In undecidable surroundings, they offer us a *sensible estimate* of what is finally derivable from some $\Gamma$. And as the proof proceeds, our insights in $\Gamma$ increase and the resulting estimate becomes *more reliable*—the estimated set of final consequences converges towards the set of final consequences. As no other means (except for tableau methods that are in this sense equivalent to proofs) is able to offer us such an estimate, dynamic proofs are extremely valuable. They provide a provisional justification in situations where a final justification is beyond our reach.[18]

By now, many inconsistency-adaptive logics have been studied (see [37], [40], [39], [22], [29], [18], and [17]), their use to several domains of application has been shown (see [5], [11], [26], and [30]), and several other logics (some non-monotonic logics, see [9] and [22], and all consequence relations defined from the Rescher-Manor mechanism (see [18]) have been integrated. I refer to [17] for a survey.

Inconsistency-adaptive logics have a nice and intuitive semantics. Moreover, their metatheory has been studied. We know their limitations and their force. Even if these are different from those of logics such as **CL**, inconsistency-adaptive logics are decent formal logics in all respects. Moreover, there is a wide variety of them. This enables one to pick the right choice in a given situation.

Suppose that, according to some theory, both $A$ and $\sim A$ are false. The only way to express this in **CL** is by such formulas as $\sim(A \vee \sim A)$ and $(A \vee \sim A) \supset \bot$. All of these lead to $\sim$-inconsistencies in **CL**. But obviously the problem is $\sim$-incompleteness rather than $\sim$-inconsistency. It is easy to devise paracomplete logics (allowing for the falsehood of both $A$ and $\sim A$), and it is easy to devise from them adaptive logics that interpret incomplete theories as completely as possible.

There are other logical abnormalities, apart from gluts and gaps with respect to negation. Kyburgh's famous [23] contains a plea against Adjunction: accepting $A$ and $B$ should not force one to accept $A \wedge B$. To realize this, one needs a logic that allows for gaps with respect to conjunction. The same procedure may be repeated with respect to all other logical constants, including identity. This provides us with a set of logics that allow all logical constants to behave abnormally in one way or the other (with respect to their Introduction Rule or with respect to their Elimination Rule). Handling abnormalities, however, does not end here.

Sometimes the **CL**-closure of a set of formulas (or sentences) is inconsistent because some non-logical constants are *ambiguous*. The first adaptive logic taking this into account is presented in [38]. In this case, "normality" does not refer to properties of the logical constants, but to the *interpretation* of the premises. The normal interpretation presupposes that each occurrence of some non-logical constant has the same meaning; that two such occurrences have a different meaning is considered as an abnormality. Technically, the matter is handled by attaching a different index (a superscripted number) to each such occurrence in both the premises and the purported conclusion. If the premises have a normal interpretation, the adaptive logic will deliver this. If they do not,

[18] In the previous sections, I sufficiently argued that one should stay content with provisional justifications. Those who doubt that this such forms of uncertainty might enter the domain of logic and mathematics should remember Gödel's second theorem. Ever since Gödel, we *know* that we are studying Arithmetic (and other mathematical theories) on the justified but unprovable supposition that it is consistent.

the abnormalities will be localized.

Abnormalities in the logical constants as well as in the non-logical constants are handled by abnormality-adaptive logics. One cannot know beforehand which abnormalities might arise in a specific context, but even this is not a problem. Abnormality-adaptive logics may be combined, and one may even devise a logic that is capable of handling all kinds of abnormalities at the same time—see [14].

And yet, we did not reach the limits of adaptive logics. The Ghent Group recently discovered adaptive logics that have nothing to do with logical abnormalities. Forthcoming results concern compatibility (and consistent extensions of theories), abduction,[19] and analogy.[20] In view of these results, the notion of an adaptive logic was redefined (see [15]).

By present lights, adaptive logics provide proof theories for forms of reasoning that are not only non-decidable, but for which there even is no positive test. This typically obtains for forms of reasoning that are non-monotonic[21] and display an internal dynamics,[22] provided the inference relation is well-defined with respect to some monotonic logic—the definition may include negative conditions such as $\Gamma \nvdash_{\mathbf{L}} A$. (If this is correct, the result has dramatic consequences.) In view of the block semantics (see [10] and [12]), the abstract definition may easily be turned into an integrity criterion (determining which lines of a proof should be marked at a stage).

At this point, I can finally come to the philosophical conclusion to be drawn from the above. Many creative problem solving processes include forms of reasoning that may only be captured by adaptive logics. This is obvious for inconsistent constraints—a well-known 'defect' of some problem solving situations—see already [33]. As is candidly shown in [26], only inconsistency-adaptive logics enable us to understand what is going on from a logical point of view in such situations. Sometimes other abnormalities are involved. They all surface as inconsistencies in **CL**, but abnormality-adaptive logics that are not inconsistency-adaptive are provably better fit to handle such situations (as they locate the problem in a more specific way). The use of other adaptive logics is rather straightforward. In almost any creative process, the compatibility of new hypotheses with a given theory is the central question. In many creative processes, abduction and analogy are sensible hypothesis generating means. Where all such inferential relations are not only beyond the reach of **CL** but even beyond the reach of logic as conceived on the traditional view (that is, alas, shared by many non-standard logicians), adaptive logics offer a formally and philosophically decent way to handle them.

[19] I bluntly admit that I have long considered abduction as fully incomprehensible. Most of the literature on the topic simply seems to advocate 'affirming the consequent'. Smarter authors remark that this works only in specific situations, but fail to specify them. The forthcoming results on abduction provide us with a decent (non-monotonic) derivability relation that made me 'see the light'.

[20] The ideas for these adaptive logics are all due to Joke Meheus. See, *e.g.*, [28] on analogies.

[21] An inference relation "$\vdash_{\mathbf{L}}$" is monotonic iff $\Gamma \vdash_{\mathbf{L}} A$ entails $\Gamma \cup \Delta \vdash_{\mathbf{L}} A$.

[22] The fact that a conclusion may be withdrawn in view of a further analysis of the premises, even if no new information interferes.

## 8 In Conclusion

As a result of the western philosophical tradition, many people still view creativity as a phenomenon that transcends rationality. I have tried to argue that they are mistaken for two (distinct but connected) reasons: a distorted view on rationality and problem solving and a too restricted view on logic. In both instances, I offered alternatives, and argued that an approach that is sensible for independent reasons brings creativity within the reach of rationality.

By now, the connection between adaptive logics and the epistemological views defended here should be clear. Adaptive logics lead to dynamic proofs. The latter provide the kind of provisional and fallible conclusions that are so typical for relative rationality.

I realize that my position entails a severe criticism of the western philosophical tradition. Nevertheless, I am not merely rejecting that tradition. To the contrary, I have been struggling with it for the last twenty years and it was a major source of self-criticism. Moreover, every section of this paper contains another attempt to safeguard two central aspects of the western tradition: rationality and logic. Ever since the seventeenth century, any progress with respect to either of these has been due to people that rejected earlier views. In this respect, the incorporation of creativity is just another step in the same direction.

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