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»THE LOGICAL CATEGORIES OF LEARNING AND COMMUNICATION« — *reconsidered from a polycontextural point of view*

— learning in machines and living systems —

Abstract

Purpose—Bateson's model of classifying different types of learning will be analyzed from a logical and technical point of view. While learning_0 has been realized for chess playing computers, learning I turns out today as the basic concept of artificial neural nets (ANN). All models of ANN are basically (non linear) data filters, which is the idea behind simple and behavioristic input-output models.

Design/methodology/approach—We will discuss technical systems designed on the concept of learning 0 and learning I and we will demonstrate that these models do not have an environment, i.e. they are non-cognitive and therefore "non-learning" systems.

Findings—Models based on Bateson's category of learning II differ fundamentally from learning 0 and I. They cannot be modeled any longer on the basis of classical (mono-contextural) logics. Technical artifacts which belong to this category have to be able to change their algorithms (behavior) by their own effort. Learning II turns out as a process which cannot be described or modeled on a sequential time axis. Learning II as a process belongs to the category of (parallel interwoven) heterarchical-hierarchical process-structures.

Originality/value—In order to model this kind of process-structures the polycontextural theory has to be used—a theory which was introduced by the German-American philosopher and logician Gotthard Günther (1900-1984) and has been further developed by Rudolf Kaehr and others.

Keywords: machine learning, polycontexturality, standpoint dependency

Paper type—conceptual paper

Introduction

Bateson himself summarizes his logical categories of learning as follows (Bateson, p.293):

> **Zero learning** is characterized by *specificity of response*, which—right or wrong—is not subject to correction.
>
> **Learning I** is *a change in specificity of response* by correction of errors of choice within a set of alternatives.
>
> **Learning II** is *change in the process of Learning I*, e.g., a corrective change in the set of alternatives from which choice is made, or it is a change in how the sequence of experience is punctuated.
>
> **Learning III** is *a change in the process of Learning II*, e.g., a corrective change in the system of sets of alternatives from which choice is made. (We shall see later that to demand this level of performance of some men and some mammals is sometimes pathogenic.)
>
> **Learning IV** would be *a change in Learning III*, but probably does not occur in any adult living organism on this earth. Evolutionary process has, however, created organisms whose ontogeny brings them to Level III. The combination of phylogenesis with ontogenesis, in fact, achieves Level IV.

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In the following we will discuss some of the questions already raised by Bateson himself:

> "… The question is not, "Can machines learn?" but what level or order of learning does a given machine achieve?" (Bateson, 1972, p. 284).

Nearly half a century later the answer is very simple: *Zero learning* has been realized, for example, by Deep Blue—a chess-playing computer developed by IBM in 1997—a machine which defeated the world champion Garry Kasparov. This event obviously affected modern economists so much that they still believe that von Neumann's game theory—which forms the basis of all algorithms underlying models such as Deep Blue—is the up to date theoretical highlight for modelling and understanding economic behavior.[1] From an epistemological point of view all these game models belong to Bateson's category of *zero learning*. Phenomena which approach this degree of simplicity occur in various contexts such as

> "… in simple electronic circuits, *where the circuit structure is not itself subject to change resulting from the passage of impulses within the circuit*—i.e., where the causal links between »stimulus« and »response« are as the engineers say »soldered in«."(Bateson, 1972, p. 284).

Today one could argue differently, e.g.: phenomena which approach this degree of simplicity occur in algorithms, *where neither the instructions nor the data are subject to changes resulting from the passage through the set of instruction (the program)*—i.e., where the causal links between »stimulus« and »response« are pre-determined by the designer of the program.

In other words, if such a game will be repeated with the same moves, the result of the game always will be the same, i.e., the machine or the (zero order) algorithm does not learn anything at all.

Learning I also has been realized technically: The best known example are the models of artificial neural nets. In analogy to zero order learning, one could describe first order learning as a "process where the data—but not the instructions(!)—of a learning algorithm are subject to changes resulting from the passage through the program and where the causal links between »stimulus« and »response« are again pre-determined by the programmer". From a conceptual point of view these models are digital (non-linear) data filters. The written down sequence of learning steps appears formally as a Markov chain and therefore is completely determined. Other models which belong to this category of "learning" are Genetic Algorithms where the data are adapted to a given fitness function by trial and error.

There is another important argument which was pointed out by Bateson in connection with *learning I*:

> "Note that in all cases of Learning I, there is in our description an assumption about the »context«. This assumption must be made explicit. The definition of Learning I assumes that the buzzer (the stimulus) is somehow the »same« at Time 1 and at Time 2. And this assumption of »sameness« must also delimit the »context«, which must (theoretically) be the same at both times. It follows that the events which occurred at Time 1 are not, in our description, included in our definition of the context at Time 2, because to include them would at once create a gross difference between "context at Time 1" and »context at Time 2«. (To paraphrase Heraclitus: »No man can go to bed with the same girl for the first time twice.«)
>
> The conventional assumption that context can be repeated, at least in some cases, is one which the writer adopts in this essay as a cornerstone of the thesis that the study

> of behavior must be ordered according to the Theory of Logical Types. *Without* the assumption of repeatable context (and the hypothesis that *for the organisms* which we study the sequence of experience is really somehow punctuated in this manner), it would follow that all »learning« would be of one type: namely, all would be zero learning." (Bateson, 1972, p. 288)

All technical models which are known today and which have been realized fulfill the condition of a repeatable context. The reason is very simple: All technical models have one feature in common—they have no environment and hence no changing contexts. For example: A robot working at an assembly line in a car manufacturing process only has an environment from the standpoint of an observer of both the robot and the assembly line. From a "standpoint of the robot", however, the robot does not have an environment. Such a robot even does not have its own standpoint. All the "environment" which is important for the functioning of the robot such as the screws or the car body, where the screws have to be fixed, are parts of the robot program and therefore belong to the robot and not to its environment—these robots neither have an environment nor an own standpoint.

Standpoint dependency is a necessity for modeling situations with changing contexts!

Classical mathematics and logic—which form the basis for any technical construct today—do not allow modeling of standpoint dependencies. Or, to phrase it in a somewhat shortened way: So far as mathematics is concerned, the result of 2_times_2 does not depend on standpoints and by analogy *all the classic standard and non-standard logic conceptions are non-standpoint dependent calculi*—or to put it in the terminology of Gotthard Günther *they are mono-contextural calculi*.

Learning II, III, IV *or* … the *Tower of Babel*

As an example where *learning II* has been recorded Bateson refers to the cases such as "reversal learning":

> "Typically in these experiments the subject is first taught a binary discrimination. When this has been learned to criterion, the meaning of the stimuli is reversed. If X initially "meant" R_1, and Y initially meant R_2, then after reversal X comes to mean R_2, and Y comes to mean R_1. Again the trials are run to criterion when again the meanings are reversed. In these experiments, the crucial question is: Does the subject learn about the reversal? I.e., after a series of reversals, does the subject reach criterion in fewer trials than he did at the beginning of the series?" (Bateson, 1972, p. 296)

From the two patterns in Figure 1 the process of reversal learning can easily be retraced: Any neural net model can be adapted to pattern 1. If the net algorithm has been trained successfully to pattern 1 then pattern 2 will be offered and the adapting process starts again until the net algorithm is adapted to pattern 2. Thereafter the adaptation of pattern 1 begins again and so forth. The crucial question is: What does the net algorithm learn (by its own effort) from the reversion of the task? For learning algorithms that belong to the category of learning II one has to expect a shortening of the learning time for the two processes of adaptation. For the models of artificial neural nets, however, nobody would expect and nobody ever has observed a shortening of the so-called learning process by reversion of the two adaptation processes using artificial neural net models.

The question arises:

a) What is the difference between *learning I* and *learning II* from an algorithmic point of view?

And furthermore one has to ask:

b) Why "from an algorithmic point of view" and not from the view of logical types?

The second question already has been answered by Bateson himself, because …

> "… the word »learning« undoubtedly denotes change of some kind. To say what kind of change is a delicate matter…. Change denotes process. But processes are themselves subject to »change« …" (Bateson, 1972, p.283)

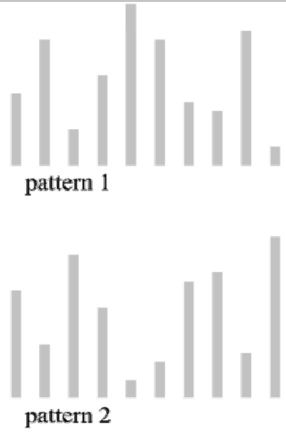

Figure 1: pattern for "reversal learning"

and

> " …the world of action, experience, organization, and learning cannot be completely mapped onto a model which excludes propositions about the relation between classes of different logical type…" (Bateson, 1972, p.307)

Processes and actions can only be modeled algorithmically with the intention to implement the model into a machine (cf., Kaehr, 2003).

An answer to the first question is much more difficult and has been given by the German-American philosopher and logician Gotthard Günther who introduced the *Theory of Polycontexturality* into life sciences (Günther, 1976, 1979a, 1980). Before we trace the main idea of this theory we have to take a short look on Bateson's *Notes on Hierarchies* (Bateson, 1972, p. 307):

> "If C_1 is a class of propositions, and C_2 is a class of propositions about the members of C_1; C_3 then being a class of propositions about the members of C_2; *how then shall we classify propositions about the relation between these classes?* For example, the proposition »As members of C_1 are to members of C_2, so members of C_2 are to members of C_3« cannot be classified within the unbranching ladder of types.
>
> The whole of this essay is built upon the premise that the relation between C_2 and C_3 can be compared with the relation between C_1 and C_2. *I have again and again taken a stance to the side of my ladder of logical types to discuss the structure of this ladder. The essay is therefore itself an example of the fact that the ladder is not unbranching*.
>
> *It follows that a next task will be to look for examples of learning which cannot be classified in terms of my hierarchy of learning but which fall to the side of this hierarchy as learning about the relation between steps of the hierarchy*." [emphasis by the authors]

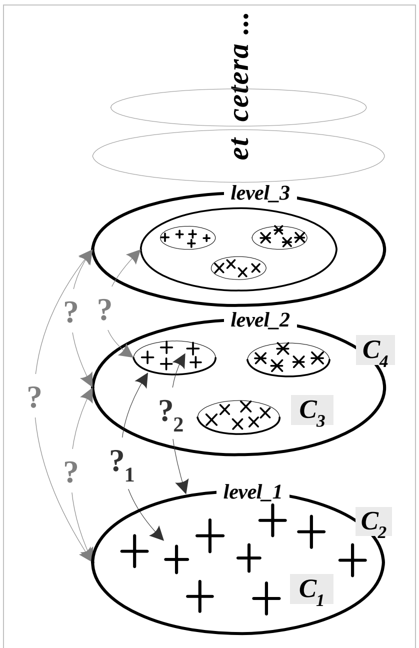

Figure 2: The hierarchy of logical types: C_1, C_2, … see text.

Figure 2 gives an example of Bateson's hierarchy of different types (classes). Based on Platon's pyramid of *Diairesis* a physical object can be defined through a generic term (*genus proximum*) and specific attributes (*differentia specifica*) such as information on the weight, length, material, or shape, etc. Each entity exists as something in particular and it has characteristics that are a part of what it is. In other words, Aristotle's *Law of Identity* strictly holds, i.e., everything that exists has a specific nature. What the pyramid of different classes (or types) in Figure 2 depicts, is the structural pattern of an absolute hierarchy where all elements are linked by a common measure. This is the well known world of natural sciences which—from a epistemological point of view—belongs to an *ontology of identity*. In other words, Bateson's categories of learning describe the *results* of different processes with attributes observed during different learning situations. From a technical point of view, however, the central question is:

How can we mode*l* the *process* of learning II ? What about the transitions between the different levels of logical types? How can these transitions be modeled in a formal mathematical way in order to develop and to implement algorithms which are able to learn in the sense of learning II by their own efforts?

Circles and '(un)branching ladders' *or* … »from classification to process« [Bateson, 1979, p.204]

For an analysis of these questions, we will introduce the following symbol for the order relation which exists between an operator $\underline{\mathbf{O}}$ and its operand O:

$$T \quad (\underline{\mathbf{O}}) \xrightarrow{\text{order relation}} F \quad (O) \qquad (1)$$

Relation (1) also stands for a *logical domain*—as it is given, e.g., in Figure 2 by the domain labeled as "level_1"—and T and F stand for true and false (or 1, 0) where an order relation exists between T and F by the rules, the syntax of the logic. A logical domain may be realized technically, for example, by the model of a Turing machine (TM), i.e., by a computer which strictly works according to the rules of classical logic. Günther introduced the notion *contexture* for a logical domain, i.e., the model of the Turing machine or today's computer are *mono-contextural* logical machines.

In the following we describe *learning I* by the relation $\underline{\mathbf{O}}$(O) which stands for an hetero-referential process as given by equation (1). Since an operator is always of logical higher type than its operand, C_2 in Figure 2 may be considered as an operator and C_1 as the corresponding operand. In order to describe *learning II* as a process, we have to ask for relations that correspond to transitions which have been marked in Figure 2, for example, by $?_1$ or $?_2$. Since classical standard logic and all non-standard derivatives as well as mathematics are mono-contextural theories, we are faced with a well known fundamental problem—the problem of self-referentiality—a problem, which has been depicted by the graphical metaphor in Figure 3.

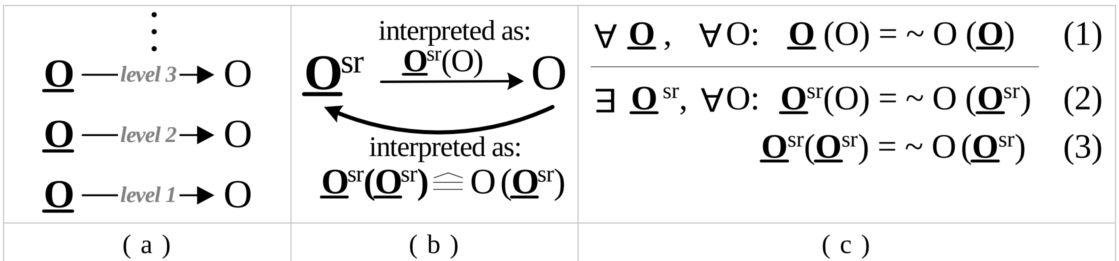

Figure 3: The problem of self-reference from a *monocontextural* point of view
~ : negation, ∀ : universal quantifier, ∃ : existential quantifier

For any modeling of cognitive-volitive *processes* one has to distinguish logically between the picture and the image of the picture or between the object and the image of the object. This has been achieved in Bateson's work—describing the *results* of learning processes—by different logical categories which leads to the hierarchy of logical types (logical domains) as shown in Figure 2. However, there are no logical operators which allow the modeling *between* the different logical types (domains)—operators which become necessary if the *process* of learning has to be modeled and not only the result, the content of a learning process.

Figure 3a shows the different logical types of Figure 2 using the symbolic metaphor of equation (1). The crucial point of Figure 3a is, to understand that the different logical domains are *not* mediated, they are isolated, i.e., there are no logical operators that allow transitions between the different logical types (domains) and their elements. And as a matter of fact any system of *n* logical types can always be reduced (type reduction) to only one logical type whereby the different processes which are the object of modeling will be homogenized to sequential process-structures that always obey the transitivity law. Therefore these processes are always hierarchically—and never heterarchically—structured; and any attempt of a formal logical description of cognitive-volitive processes ends up within the thicket of notorious *circuli vitiosi* (see also: Günther, 1979a; Kaehr & von Goldammer, 1988, 1989).

Figure 3b represents the process of hetero-referencing from the operator (cognitive system) to the operand (object), a process where an image of the object is created from which the cognitive system references on itself in order to make a distinction between itself and its environment. This is a self-referential process. From a logical point of view, this process is a vicious circle, i.e., a logical antinomy. This has been shown in Figure 3c. Relation (1) in equation 3c expresses the fact, that an order relation exists between an operator and its operand, i.e., the operand cannot become an operator of it"self". Relation (2) refers to the hetero-referential aspect of the process and relation (3) to the self-referential aspect. Needless to say that relation (3) is in contradiction with the self-referential situation in Figure 3b and within this context it can be seen, that self-referentiality cannot be modeled by recursion as suggested frequently by artificial intelligence scientists. In other words, self-reference cannot be modeled without antinomies and ambiguities within the linguistic frame of classical standard logic—the classical standard logic reveals a basic weakness as an intellectual tool for modeling *self-referential processes*.

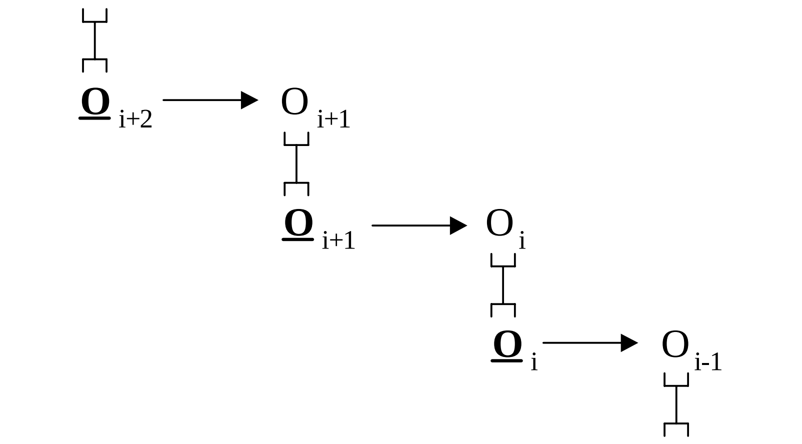

Figure 4: Self-Reference from a *polycontextrural* point of view
: exhange relation, ⟶ order relation
(for more details see: von Goldammer, E. & Kaehr, R., 1990)

In Figure 4 we have introduced a symbol for an exchange relation between an operator $\underline{\mathbf{O}}_{i+1}$ and operand O_{i+1} which belong to different logical domains respectively. Within the mono-contextural logical world no such exchange relation exists. The logical domains are mediated provided the exchange relation is based on logical operations between different logical domains (contextures). In other words, in Figure 4 different logical places come into play—a situation which has no meaning in all classical standard and non-standard logic conceptual designs. Since we are not restricted to a limited number of contextures, Figure 4 represents an ensemble of any number of *mediated contextures*. Obviously here is the ladder to escape the eye—the black hole, the abyss—of circularities. The question is, how can we work with such a ladder?

Mnemonic Traces *or* … »mental process requires circular (or more complex) chains of determination« [Bateson, 1979, p.114]

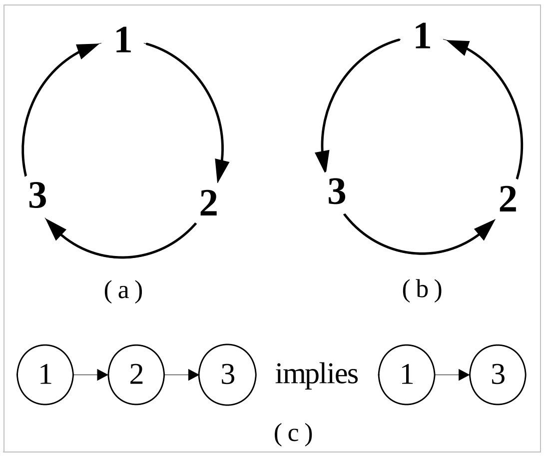

Figure 5: Günther's "heterarchical" circles

In order to demonstrate the meaning of the *mediated* contextures in Figure 4, a decision making process between three different standpoints as shown in Figure 5 will be discussed. Figure 5c reflects the transitivity law and will not be discussed anymore since it is self explaining. The arrows in Figure 5a are interpreted as follows: Standpoint S2 is preferred to standpoint S1, S3 is preferred to S2 and S1 is preferred to S3 and accordant in Figure 5b. Although the transitivity law does not hold for both processes represented by Figure 5a,b they do not symbolize a decision process if they are considered separately. The reason is very simple: In both cases a decision already has been made in advance, i.e., the three standpoints have already been arranged according to some priorities—but this should be the result of a decision process and cannot be taken for granted. To put it in other words: Any modeling of a real decision process requires coequal, equivalent standpoints during the decision making process. This can only be achieved in the symbolic representation of Figure 5a,b if both processes represented by the two circles are thought parallel and simultaneously. But this is impossible, as it was nicely described in Bateson's metalogue "How much do you know?" (Bateson, 1972, p. 21):

> D: I wanted to find out if I could think two thoughts at the same time. So I thought "It's summer" and I thought "It's winter." And then I tried to think the two thoughts together.
>
> F: Yes?
>
> D: But I found I wasn't having two thoughts. I was only having one thought *about* having two thoughts.
>
> F: Sure, that's just it. You can't mix thoughts, you can only combine them. And in the end, that means you can't count them. Because counting is really only adding things together. And you mostly can't do that.

It is not only impossible to think two thoughts at the same time, one even can neither observe or measure (directly or indirectly) a decision making process(-structure). In other words: It is in general impossible to observe or to measure mental processes such as thinking or learning. What we can observe or experience are the actions, i.e. the "products", the content of these processes but not the processes themselves.[2]

Why is it so?

The answer can be given with reference to McCulloch's undiscovered paper "*A heterarchy of values …*" (McCulloch, 1945): The structure of all mental processes is an interplay of heterarchical and hierarchical interwoven components. A heterarchical process structure is defined as a process where the transitivity law cannot be applied any longer and therefore these process-structures cannot be mapped sequentially, i.e. these process-structures never can be measured! To express it inversely: For any measurement the transitivity law strictly holds; its validity is—so to speak—a necessity for all experimental processes of measurement.

It was Gotthard Günther who provided a basis for modeling such process structures. His *polycontextural theory* not only contains a many-placed logic but also a theory of heterarchical numbers (Günther, 1976) and the *pre-logical* theory of morphogrammtic as well as the *pre-semiotical* theory of kenogrammatic (cf., Kaehr, 2003, 2004).

In the following we will demonstrate in a short and somewhat simplified way how a decision making process can be rationalized within the language of Günther's polycontextural theory, a theory which has to be considered as *the* basis for a standpoint dependent systems theory.

Again three standpoints are considered which will be indexed by natural numbers. Each number stands not only for a standpoint but also for a logical place which represents a standpoint by at least one contexture, i.e., a logical domain.[3] The following chain of negations which is very often taken as an example in the work of Gotthard Günther will be interpreted:

$$p = N_{1,\,2,\,1,\,2,\,1,\,2}\, p \qquad (2a)$$

and

$$p = N_{2,\,1,\,2,\,1,\,2,\,1}\, p \qquad (2b)$$

Where $p = N_{1,\,2,\,1,\,2,\,1,\,2}\, p$ corresponds to

$$p = N_1 (N_2 (N_1 (N_2 (N_1 (N_2\, p))))) \;=_{def} N_1 N_2 N_1 N_2 N_1 N_2\, p \qquad (3a)$$

and $p = N_{2,\,1,\,2,\,1,\,2,\,1}\, p$ corresponds to

$$p = N_2 (N_1 (N_2 (N_1 (N_2 (N_1\, p))))) \;=_{def} N_2 N_1 N_2 N_1 N_2 N_1\, p \qquad (3b)$$

The different (global) negations in (2) will be executed from the right to the left. The negation N_1 and N_2 are defined according to the table (4a, b):

p	$N_1 p$
1	2
2	1
3	3

(4a)

p	$N_2 p$
1	1
2	3
3	2

(4b)

The proposition variable p will be considered from a standpoint S1 in relation to standpoint S2 or any other standpoint. In other words, the (global) negations have to interpreted as inter-contextural negations, i.e., a contexture is negated or rejected in relation to another contexture. (3b) can be interpreted as given in the following steps:

step 1: $p = N_2 N_1 N_2 N_1 N_2 \boldsymbol{N_1}\, p$

If the propositon p is considered from S1 in relation to S2, standpoint S1 can be designated or not designated, i.e. negated or rejected. A designation (affirmation) of S1 would be the end of the inter-contextural negation process, i.e., the logical domain (contexture) corresponding to S1 would have been chosen. If, however, S1 in relation to S2 will not be designated – which is the case in our example – then an exchange of the standpoint from S1 to S2 occurs, as indicated in table (4a). Since every standpoint is characterized by at least one logical domain (contexture) this process corresponds to an exchange of standpoints. From a logical point of view it is an *inter-contextural* (or *discontextural*) *process*.

step 2: $p = N_2 N_1 N_2 N_1 \boldsymbol{N_2} N_1\, p$

Now the proposition p will be considered from standpoint S2 in relation to S3. Again the negation (or rejection) of S2 in relation to S3 is of interest, because an affirmation (or designation) of S2 would terminate the inter-contextural (discontextural) process. According to table (4b) an exchange from standpoint S2 to S3 results.

step 3: $p = N_2 N_1 N_2 \boldsymbol{N_1} N_2 N_1\, p$

Now the proposition p will be considered from S3 in relation to S1/S2 and no exchange of the standpoint occurs (cf. table 4a).

step 4: $p = N_2 N_1 \boldsymbol{N_2} N_1 N_2 N_1\, p$

Considering the proposition from S3 in relation to S2 causes an exchange from S3 to S2 (cf. table 4b).

step 5: $p = N_2 \boldsymbol{N_1} N_2 N_1 N_2 N_1\, p$

Within the range of step 5 the proposition p will be considered from standpoint S2 in relation to S1 (inversion of step 1). An exchange from S2 to S1 takes place.

step 6: $p = \boldsymbol{N_2} N_1 N_2 N_1 N_2 N_1\, p$

Step 6 can be considered as the inversion of step 3, i.e., the proposition p is considered from S1 in relation to S3/S2 and no exchange of the standpoint occurs (cf. table 4a).

At the end of such a negation circle the proposition p has a "history of reflection" as Günther calls it in the foreword of his *Beiträge…*(2nd volume) (Günther, 1979). The classical negation (~) never gains such a "history of reflection". While the inter-contextural transitions (the rejections within the negation chain) correspond to the cognitive aspects of a cognitive-volitive process. The designation of a standpoint, of a contexture on the other side corresponds to the volitive aspects of a cognitive-volitive process. For a more detailed discussion on cognition *and* volition it is referred to the literature, especially to Günther's "*Cognition and Volition*" (Günther, 1979a).

UPSHOT: The classical standard logic as well as all (classical) non-standard logics like modal-logic, probability logic, fuzzy logic, or paraconsistent logics, etc. are truth-definite in the sense of an *ontology of identity* ("something *is* or *is not*"—any third is excluded—cf. example above). Günther calls the sciences or languages based upon these truth-definite logics positive sciences or languages. All natural languages as well as the artificial languages like the classical standard- and non-standard-logics or mathematic are positive languages. **Positive languages** are characterized by their (intra-contextural) negations which *always imply indirectly the corresponding positive proposition*.

Günther's **negative language** (Günther, 1979b) can be considered as complementary to the artificial positive languages. The negative language is characterized by a variety of negations (negation chains or negation circles) which operate *inter*-contextural (not *intra*-contextural) and which are mutually mediated. Therefore any inter-contextural negation always refers to at least one further contexture, i.e., any rejection (negation) of a contexture (standpoint or logical place) is always related to at least one further contexture (standpoint or logical place) as it was demonstrated above (step 1 to 6). In other words, a contexture (standpoint or logical place) can only be negated (rejected) in relation to (at least) one further contexture. This corresponds to a process (not a state!) where the positive appears not before a contexture (standpoint or logical place) has been designated in the sense of an affirmation. From the view of the classical logic these negations are meaningless since all classical standard- and non-standard logics are *mono*-contextural, i.e., only one contexture (one standpoint, one logical place) exists which can be located only outside but not within the contexture.

Resume *or* … »time is out of joint« [Bateson, 1979, p.231]

Learning only occurs in systems with cognitive-volitive abilities. Until today no such technical devices have ever been constructed. On the basis of the classical ontology of identity one never will be able to model the cognitive-volitive abilities of living systems in a formal mathematical way—this is, so to speak the blind spot of modern brain research and of modern artificial intelligence research.

Today's situation is dominated by a scientific mainstream of brain and artificial intelligence research that neither has analyzed McCulloch's *A heterarchy of values…* nor Bateson's *Logical Categories of Learning…* and—most notably—the scientific-logical consequences of these nearly half a century old basic studies which—from a methodological point of view—are still unexcelled. With the fundamental work of Gotthard Günther the situation is even worse: it has been pointedly ignored by the scientific mainstream of artificial intelligence and brain research. And strange enough even the community of second order cybernetics was unconcerned about Günther's theoretical work and his philosophy.

Links and Further Readings

A complete bibliography of Gotthard Günther's work can be found at the electronic journal:
< http://www.vordenker.de > (Paul, J., ed.)
URL: http://www.vordenker.de/ggphilosophy/gg_bibliographie.htm

Fundamental theoretical studies of the post-Güntherian era on poly-logic, polycontexturality, morpho- and kenogrammatic by Rudolf Kaehr can be found at: < http://www.thinkartlab.com > (Kaehr, R., ed.)
`Rudolf-Kaehr-Archiv: http://www.vordenker.de/rk/rk_bibliographie.htm`

Notes

1 2005 the economists Robert J. Aumann and Thomas C. Schelling got the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel "for having enhanced our understanding of conflict and cooperation through game-theory analysis".

2 This is, so to speak, the quintessence of Varela's closure thesis (Varela, 1979)—Closure Thesis: "Every autonomous system is organizationally closed ... organizational closure is to describe a system with no input and no output ..."

3 For an implementation Günther's heterarchically structured numbers, which he called dialectical- or keno-numbers have to be used. This is of importance in present context because the heterarchically structured system of numbers prevents any formation of a hierarchy of logical types. Using natural numbers instead of keno-numbers is only one of the simplifications which we use in the presented example. We also have not mentioned the proemial relationship and its importance in Günther's *Theory of Polycontexturality*. In his scientific essay *Strukturelle Minimalbedingungen einer Theorie des objektiven Geistes als Einheit der Geschichte* (Günther, 1980, Band 3, p. 136-182) Günther describes the logical complexity underlying any formal description of mental processes. Both Günther's morphogrammatic which is a pre-logical theory and his kenogrammatic which is a pre-semiotical theory also cannot be discussed within such a short report. For more details it is referred to the literature (cf., Kaehr, 2004).

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