The Yerkish Language. From Operational Methodology to Chimpanzee Communication

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Purpose: Yerkish is an artificial language created in 1971 for the specific purpose of exploring the linguistic potential of nonhuman primates. The aim of this paper is to remind the research community of some important issues and concepts related to Yerkish that seem to have been forgotten or appear to be distorted. These are, particularly, its success, its promising aspects for future research and last but not least that it was Ernst von Glasersfeld who invented Yerkish: he coined the term "lexigrams," created the first 120 of them and designed the grammar that regulated their combination. ***Design:*** The first part of this paper begins with a short outline of the context in which the Yerkish language originated: the original LANA project. It continues by presenting the language itself in more detail: first, its design, focusing on its "lexigrams" and its "correlational" grammar (the connective functions or "correlators" and the combinations of lexigrams, or "correlations"), and then its use by the chimpanzee Lana in formulating sentences. The second part gives a brief introduction to the foundation of Yerkish in Silvio Ceccato's Operational Methodology, particularly his idea of the correlational structure of thought and concludes with the main insights that can be derived from the Yerkish experiment seen in the light of Operational Methodology. ***Findings:*** Lana's success in language learning and the success of Yerkish during the past decades are probably due to the characteristics of Yerkish, particularly its foundation in operational methodology. The operation of correlation could be what constitutes thinking in a chimpanzee and an attentional system could be what delivers the mental content that correlation assembles into triads and networks.
Research implications: Since no other assessment or explanation of Lana's performances has considered these foundational issues (findings), a new research project or program should validate the above-mentioned hypotheses, particularly the correlational structure of chimpanzee thinking.
Keywords: Yerkish, artificial language, correlational grammar, operational methodology, Silvio Ceccato, machine translation, chimpanzee communication.

Introduction

Could an ape participate in a chat session over the Internet? At first sight the question may seem silly, but I claim that it could – at least in part – be taken seriously and in this paper I will try to show why. To begin with, let us step back a little and have a look at some questions that the scientific community would probably accept as more "sound." Is language no longer the exclusive domain of man? Can an ape create a sentence? Are explanations of language learning and use by an ape also useful for understanding some of the abilities involved in human language and vice-versa? How can these questions be answered in a scientific manner?

Today science seems to have overcome the old behaviourist stimulus–response bond and finds itself in a somewhat better position to try to answer this and related questions. But about 40 years ago, when Ernst von Glasersfeld created "Yerkish" – an artificial language for use by apes in computer-mediated communication (CMC) with machines and humans – the situation was much more uncomfortable.

Origins of Yerkish – The LANA project

One day in the fall of 1970 Ray Carpenter, one of the fathers of primatology in the United States, came to the almost regular Saturday golf meeting with von Glaserfeld bringing with him an intriguing idea: The Yerkes National Primate Research Center in Atlanta[1] (Georgia), the first and foremost institute of primate research in the USA, was planning to investigate the possibility of communication between humans and great apes via a computer by means of a visual language. The great apes (gorillas, orangutans, chimpanzees) would probably never learn a spoken language, Carpenter said, but they were quick and clever with their fingers and Alan and Beatrice Gardner had successfully taught ASL (the American Sign Language used by deaf people) to a chimpanzee called Washoe.[2]

Despite impressive results in teaching sign language to the great apes, in those years as well as during the following two decades, linguists and psychologists – who wanted to believe with Chomsky that language was a human prerogative – doubted that "*an ape can truly create a sentence*" (Terrace et al. 1979, p. 891) and claimed that "*they show no unequivocal evidence of mastering the conversational semantics or syntactic organization of language*" (Terrace et al. 1979, p. 901). They also said that sign language did not have a proper syntax and therefore was not really a language. Moreover they suggested that the Gardners were like parents with a baby: they saw and heard demonstrations of linguistic capabilities that no one else could see or hear.

The Yerkes Center plan was to build a communication system with a simplified language, a keyboard, and a small computer to explore computer-mediated communication between humans and apes. The computer would record everything the ape typed on the keyboard and there would be no subjective bias as to what the ape had or had not typed. This plan seemed a great idea to von Glasersfeld and when Carpenter asked him if he would like to design the special language and the computer system for handling it, he immediately accepted. In his turn, von Glasersfeld recommended that his long-term research partner Pier Paolo Pisani[3], a computer specialist, also join the effort.

After a number of conferences among the members of the project team, in early winter 1970 a proposal was submitted to the National Institute of Health requesting funds for a 4-year period. In spring 1971 the grant was awarded (NIH grants HD-06016[4]and RR-00165). The team immediately began designing and building the system and a few weeks later everyone was introduced to the subject of the research, a young female chimpanzee called Lana (born October 7, 1970).[5]

In the first phase of the project a Plexiglas cubicle the size of a small room was built on to an existing wall that had a window to the outside of the Yerkes Center. One of the Plexiglas walls was dedicated to the keyboard, a square array unit of initially 5x5 keys, with space for other units to be added as Lana got more proficient. By sequentially pressing the keys of the keyboard, code signals standing for words were sent to the computer, which contained the vocabulary and the grammar of Yerkish, the automatic parser for checking the correctness of sentences, and the rules for activating a dispenser in response to requests that Lana was to formulate in Yerkish word symbols (Glasersfeld 1995, p. 11). The computer itself and the terminal with a keyboard for the researchers were placed just outside the room: from here the experimenters could interact with Lana by typing sentences that were displayed above her keyboard and they could also see how she was behaving during the computer-mediated communication session.[6]

Next to Lana's keyboard was the row of food and drink dispensers, activated through the computer; they would provide all sorts of food and drink (like apple, bread, chow, banana, milk, juice etc.) and it was hoped that Lana would learn to feed herself by means of request sentences typed on the keyboard. Beside providing food and drink, the computer could respond to correctly formulated requests by playing taped music or sounds, projecting movies and slides as well as opening and shutting the above-mentioned window. Above the keyboard was a sturdy horizontal bar that Lana had to hang on to in order to switch on the system (Fig. 1).

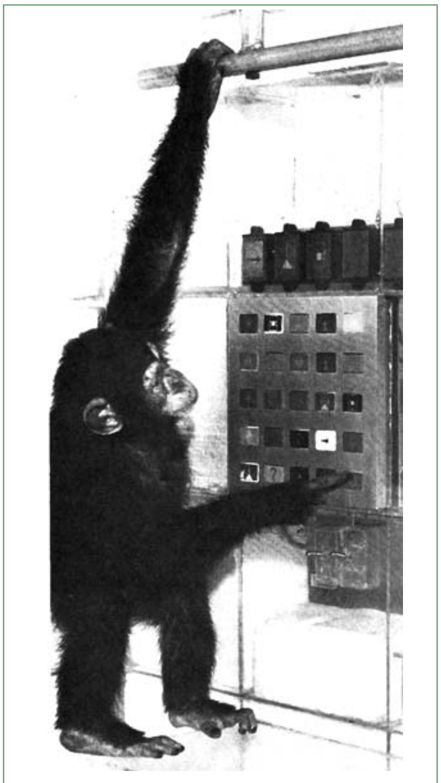

Figure 1: Lana at the lexigram board. Photo Ernst von Glasersfeld.

The Yerkish language

Language as a communicatory system has three indispensable characteristics (Glasersfeld 1977a, p. 66): a) it has a set, or lexicon, of artificial signs; b) it has a set of rules, or grammar, that governs the creation of sentences as sequences of lexical entries; c) its signs are used as symbols (Glasersfeld 1974).

The lexicon of Yerkish was developed by von Glasersfeld starting from a list of things that would presumably interest a young chimpanzee (and the experimenters) and could be available in the project. The words of this preliminary vocabulary were about 150, but in the beginning only 25 were put on the first panel of keys. Each key had an abstract design representing not a letter but the "word-design" for a single concept. Ernst von Glasersfeld coined for these word-designs the name "lexigrams" and created them by means of non-representational design elements to emphasize their symbol-character (Fig. 2) and to prevent critical linguists from saying that Lana recognized them just because they were familiar pictures. Whenever Lana pressed keys the respective lexigrams were projected on to a row of small windows above the keyboard, one after the other from left to right. This helped Lana to see how far along she was in typing the sentence – seven was the maximum length of a sentence. Moreover projecting the lexigrams in this row was used to flash messages from the human trainers to Lana and to make conversations possible.

After compiling the lexicon of Yerkish, the lexical items were divided into classes. Since Yerkish was designed on the basis of a "correlational" approach to language (Glasersfeld 1970), the lexigram-classes were defined in terms of the functional characteristics of concepts and not, as in a traditional lexicon, in terms of morphology and the roles they would play in sentences (noun, verb, adjective, etc.). For instance, items with functional characteristics like being able to eat, drink, groom, tickle, give things or make things happen were collected in the lexigram class "autonomous actor" and divided into four sub-groups: "familiar primates" (lexigram *Lana* and lexigrams for the first names of technicians and experimenters, like *Tim* or *Shelley*), "unfamiliar primates" (lexigram *visitor*), "nonprimates" (lexigram *roach*) and "inanimate actor" (lexigram *machine*). Several lexigrams were assigned to classes designating relational concepts like the class "partitive proposition" (lexigram *of*), the class "semantic indicator" (lexigram *name-of*) and the class "attributive marker" (lexigram *which-is*).

Like the lexicon, the grammar of Yerkish was also "correlational": in fact von Glasersfeld derived it from the correlational grammar implemented from 1960 to 1970 in his projects for the machine translation of English sentences (Hutchins 2000). As a consequence the Yerkish grammar was an interpretive device and consisted of the rules of a

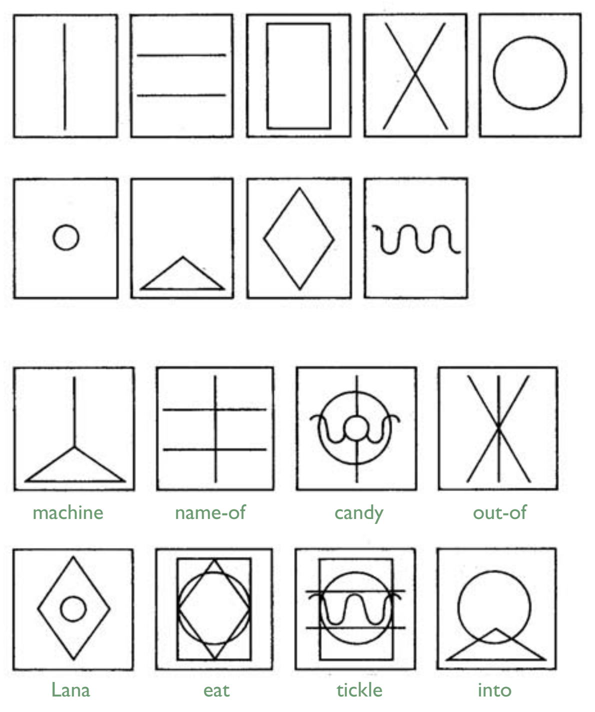

Figure 2: Lexigrams table developed by von Glasersfeld in 1971.

primitive syntax that governed which lexigram sequences (i.e., sentences) were to be considered correct (i.e., any input that it could interpret) and which mistaken (any input that it could not). There were three classes of sentences: statements, requests, and questions. Requests were differentiated from the others by first pressing a key called “please”; questions had to begin with a question mark. To know when to check the correctness of Lana’s typing, the computer needed a signal to indicate the end of a sentence, like a period.

The correlational approach to language is based on the assumption that sentences express in language sequences of mental operations (attentional operations) performed at the cognitive level (Ceccato 1964, p. 14). The most important among the mental operations are obviously those that establish connections among conceptual operands and thus build up complex structures. These relational concepts, that Ceccato called *correlators* (Ceccato et al. 1961, p. 36), are connective functions used at the mental level in the process of correlating. In natural languages correlators are indicated in a variety of ways, either implicitly or explicitely. A correlator is always a binary function in that it links two mental operands – expressed in language by either single words or word combinations – and thus forms a new unit (a triad) called a “correlation” (Fig. 3). Implicit correlators are indicated in phrases or sentences merely by the juxtaposition of the two lexical items they link, and “explicit” correlators are indicated by specific words (such as propositions, conjunctions, etc.). In the following we will use “correlator” both for the relational concepts and for the linguistic devices that express them.

In 1974 the Yerkish grammar used by Lana operated with some 30 correlators. Five of these are, for example, correlators that connect an operand of the class “actor” with an operand of the class “activity.” In the following examples we designate the correlators by the letter “C” and the number used to identify them in the LANA project; a correlation is then written as list of correlators and operands using Polish notation (prefix notation with operators left of their operands). Examples of sentences and their correlations in Yerkish:

1. Lana drink
   (C_01 Lana drink)
2. Tim carry Lana
   (C_02 Tim (C_14 carry Lana))
3. Please machine give M&M
   (C_00 Please (C_05 machine (C_017 give M&M)))
4. Please machine make movie
   (C_00 Please (C_06 machine (C_18 make movie)))
5. Please machine give piece of banana
   (C_00 Please (C_05 machine (C_17 give (C_026 (C_25 piece of) banana))))

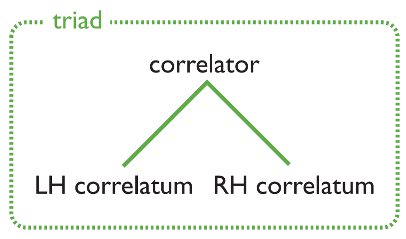

Figure 3: A correlator as a binary function.

6. Please Tim give milk to Lana
   (C_00 Please (C_05 Tim (C_21 (C_17 give milk) (C_22 to Lana))))
7. Tim give apple which-is red to Lana
   (C_05 Tim (C_21 (C_17 give (C_31 apple (C_10 which-is red))) (C_22 to Lana)))
8. Please Tim move out-of room
   (C_00 Please (C_07 Tim (C_21 move (C_22 out-of room))))
9. Please Shelley move behind room
   (C_00 Please (C_07 Shelley (C_21 move (C_22 behind room))))

Compare the sentences of example 1 and 2. They require two different correlators C_01 and C_02 because the performed activity they link with the actor performing them are different: correlator C_01 (example 1) connects an autonomous animate actor with a *stationary activity* whereas correlator C_02 (example 2) connects an autonomous animate actor with a *transferring activity*.

Sentences 3 and 4, although very similar, require two different correlators C_05 and C_06 because the intended effect they link with the agent causing it are different: correlator C_05 (example 3) connects a causative agent with a change of position whereas correlator C_06 (example 4) connects a causative agent with a change of state.

Use of Yerkish by Lana (chimpanzee)

Lana’s training began with a panel of three or four keys for learning a set of preliminaries, such as that it was the sequence of lexigrams in the row of windows above the keyboard that counted, not their position in the panel, or that it was always necessary to press the period key at the end of a sentence. She first learned to press a single key in order to obtain a piece of food or an M&M candy. Lana progressed rapidly in her training and within the first 2 weeks of training she learned to concatenate keys to form a stock sentence like "Please machine give M&M" (example 3) or "Please machine make movie" (example 4).

When she got the first 25-lexigrams panel, she quickly learned to watch the row of windows above the keyboard to check what she had typed. It took her no time to find out that when she made a typing error she could erase what she had typed by pressing the period key (which made the computer cancel the input because it contained an error). Lana learned not only to use several stock sentences appropriately, but also to build novel sentences that were syntactically correct.

Unfortunately the director of the project was convinced that understanding in communication with Lana could be proved statistically: as a consequence, in order to collect statistical evidence of her "skills," Lana was subjected to repetitive tests like a rat in a maze. It was clear from simply watching her behaviour, that, like a human child, she lost interest after the nth repetition and pressed keys without looking. Her statistics therefore tended to be worse than those of rats. On the other hand, she did things that no rat could ever do. When Tim, the graduate student who worked with her in these experiments, repeated the same question for the nth time, she typed in the response: "*Please Tim move out of room*" (see example 8). This was above all remarkable because Lana had encountered expressions such as "out of," "in front of," and "behind" only in the context of boxes and wooden blocks on a table and the notion that her room was a kind of box you could "move out of" was entirely her own. On another occasion, when Shelley appeared outside the Plexiglas cubicle, Lana, rushed to the keyboard and typed: "*Please Shelley move behind room*" (see example 9). Shelley, who had no idea what it could mean, did not take any action so that Lana, who was expecting a specific intervention, threw up both her arms in an unmistakable human-like gesture of despair and once more typed the same phrase. Eventually Shelley looked at the array of dispensers and noticed that the one for slices of banana had got stuck. She went out of the cubicle and to the other side of the transparent wall – which from Lana's point of view could quite reasonably be conceptualized as "behind room." Lana watched her clear the dispenser and immediately typed: "*Please machine give piece of banana*" (see example 5). On this and many other similar occasions, Lana, by means of original, spontaneous, and appropriate utterances, made it quite clear that she was indeed capable of forming concepts and able to use the lexigrams in language. Lana demonstrated that she was able to participate in a manner of living that we call language, i.e., that she could experience a recursive coordination of behavioural coordinations, a process which allowed her to have a recursive influence on what she was experiencing.

In September 1974 Lana's lexigram board consisted of 3 panels of 25 keys each (Glasersfeld 1977b, p. 128). The total of 1577 grammatical 6-lexigram strings produced by Lana in this month can be assigned to 125 sentence types. Four types are requests for food and account for 1288 tokens. Of the remaining 289 tokens, 228 represent 76 types that were spontaneously formulated by Lana – none of them were produced as a result of training. In some cases their occurrence was even a rather imaginative transference of a meaning acquired in a very specific context to a substantially different context.

These and similar facts persuaded von Glasersfeld that Lana was well able to communicate by means of symbols and also clearly indicated that understanding communication with Lana could not be tested statistically but shown only by the appropriateness of individual utterances. Unfortunately they did not convince the conventional experimental psychologists involved in the LANA project of the necessity to devise more appropriate research methods.

Later experiments in other projects (Savage-Rumbaugh et al. 1980) suggested that Lana had difficulties in expanding her linguistic domain[7] beyond the limits of the domain of interactions through a computer in which she had participated. On the other hand Kanzi, a bonobo, though he had never been taught, learned Yerkish very well and even some English by simply listening and participating in the laboratory environment during his mother Matata's training sessions (Savage-Rumbaugh & Lewin 1994).

Silvio Ceccato and the correlational structure of thought

The correlational approach to language that von Glasersfeld applied in developing Yerkish was based on investigations of mental activities that Silvio Ceccato had begun in 1939 (Ceccato 1964/1966). Together with a group of scholars living in Italy he proposed from the beginning to study thought and its contents in terms of operations (Ceccato 1951, 1953). Because of this "operational approach" or "operational methodology," Ceccato's group was called the "Italian Operational School." His research activity was devoted to understanding the basic structure and dynamics of thought production, to the development of an operational solution to the problem of semantics (connection of thought and language) and to applications of operational methodology in machine translation experiments.

The basic assumption of operational methodology is that the essential function (or activity) for the constitution of any mental content is the function of attention. In fact, it is easy to notice that without attention we do not have mental content, i.e., no mental life. Our clothes are in contact with our body: do we feel them? Not if we do not pay attention to them. We are typing on the computer keyboard: are we aware of our finger touching a key? Not if we do not pay attention to it. Similarly we do not notice the noise of traffic outside or understand what someone in the group is saying if we do not pay attention. In other words, the dynamism of physical interaction between our organism and our surroundings proceeds on its own account without constituting any mental content unless we direct our attention to the functioning of the different organs of hearing, touch, etc.

Attention, however, is not limited to this function of making present the functioning of other organs; in fact, attention is not applied continuously but for discrete intervals of time, ranging from a tenth of a second to a second and a half: after this time, attention detaches itself and after a short pause can be applied again. In this way, as it is applied and detached repeatedly, it fragments into discrete pieces (so-called "praesentiata" or recepts) the functioning of other organs and builds an oscillation similar to alpha waves in the brain or to the rhythmic contractions of the heart. This conception of a pulsating attention and of discrete microunits of mental activity has been recently confirmed by neurophysiological experiments suggesting that "the seemingly continuous stream of consciousness consists of separable building blocks" (Lehmann et al. 1998, 2000).

A third function of attention could be called the "generating" function. Why? Because it allows attention not only to be applied to other organs but to be applied to nothing (a state of simple vigilance, an empty attention) or to its own functioning instead, thus generating discrete attentional fragments that are not pieces of hearing, touch, vision or other sensorial activity but purely attentional microunits (attentional states).

We would however never build a seemingly continuous stream of consciousness, if there were not:

1. "Categorization" as the function which enables the mind to produce *concepts* by combining attentional states into more complex combinations (macrounits).
2. "Perception" as the function which enables the mind to produce *percepts* by applying some results of categorization to recepts.
3. "Correlation" as the function which enables the mind to assemble concepts and percepts into thoughts.

The operation of categorization received this name because it produces mental constructs that Ceccato, in honor of Kant has called "mental categories." Thus mental categories comprise those mental constructs which are made only by combinations of discrete attentional fragments and do not contain anything originating from observation. Examples of mental categories are the more or less complex combinations (concepts) of attentional microunits designated by words like "thing," "object," "beginning," "end," "part," "whole," "element," "group," "set," "point," "line," "and," "or," "singular," "plural," "space," "time," "number," "1," "2," "3," etc. Each category is differentiated from the others by the number of discrete attentional states (fragments) which it comprises and by the way in which they are combined.

The operation of correlating is what constitutes thinking. It assembles the attentional units in a binary tree. The basic structure of thought, according to Silvio Ceccato is always a triad, called a "correlation," composed of two correlates assembled together by a correlator (Ceccato 1961, 1967). This triad has a characteristic dynamism, an order of operational precedence in that the first correlate, or first mental construct is the first in time to be constituted (or activated) and is then held present (active) during the constitution of the correlator, which in its turn is held present during the constitution of the second correlate, or second mental construct. The correlates can be concepts, percepts or entire thoughts but the correlator is always a purely attentional microunit, a mental category.

Correlation constitutes the dynamism of thought, of which the triad is the smallest unit. The larger units of thought are obtained by using a correlation as a term in another correlation, which in its turn can become a part of a third correlation, and so on, until a greater or smaller correlational network is assembled. Pronouns and other words with recall functions then make it possible for complete correlational networks to be reused as elements in other correlations.

Language and thought

A fundamental function of language consists in ensuring that thoughts can be reified. One way of reifying thoughts is by designating them, i.e., by establishing a viable correspondence between the polyphonic structure of thought and a linear sequence of perceivable items.

Given a background of an operational methodology, with its attentional model of mental contents and its correlational model of thinking, we are now in a position to explain language in a completely different way: an operational way!

Traditional grammars explain, for instance, vocabulary items (the lexicon) by assigning them as elements to classes such as "noun," verb," "adjective," etc. by virtue of some feature that is identified as common to all the members of a class. Since many members do not display all the required characteristics of their class, grammars usually proceed by subdividing a class according to the specific or "exceptional" features of certain items. One might call this the botanist's, zoologist's or retailer's approach: as with trees, flowers, birds, reptiles, dishwashers or chairs this kind of explanation is useful with the word items of a natural language only for the purpose of describing a catalogue.

However, for users and developers of a language – for instance children acquiring it from their interactions or machine translation researchers using it in experiments – the main purpose is not description but the interpretation and production of sentences, i.e., of combinations of items. For this reason the usefulness of the explanation depends on its ability to accurately specify in operational (functional) terms the items involved. This characterisation in functional terms is exactly what the correlational approach provides by means of a minute and rigorous discrimination of a word-item's eligibility as correlatum or correlator within a correlation (Glasersfeld & Pisani 1968, pp. 1–2).

To reify a simple correlation into a linguistic form, each single element must be designated by means of at least two indications: one to say what it is (referential function) and the other to say what function it performs in

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the correlation (correlational function), whether that of correlator or that of first (left hand) or second (right hand) correlatum. In order to supply these indications, languages can offer basically two means: on the one hand they use a particular, phonic or graphic material (spoken or written words), and on the other hand they use the order of succession into which this material is put (word sequence). Only by providing these six indications can we identify two expressions such as "green bottle" and "bottle green" as two different correlations or units of thought.

Mostly a correlation will be designated by employing two or three words (or whole sentences in a correlational net), which is to say, the required indications are distributed among two or three words, but usually the correlations that occur more frequently are indicated by only two words, one for the first and one for the second correlatum, whereas the correlator remains tacit. How can we understand a correlation of this kind in which there is no explicit word for the correlator? In some cases the correlator is indicated by changes in the form of the designation of one of the correlates but in all other cases the indication of the appropriate correlator has to be deduced from a wide-spread knowledge, a common cultural heritage behind any language, for which Ceccato has coined the terms "Notional Sphere" (Ceccato 1961 et al., p. 62) and "Constellation" (Ceccato 1961 et al., p. 63), which were precursors of methods of knowledge representation such as frames and scripts in early Artificial Intelligence research (Sowa 1984, p. 128). Knowing how certain things are related allows the designation to be made more efficiently by reducing the number of explicit indications, thus making communication more rapid, flexible and adjustable (Ceccato & Zonta 1980, p. 78). For example, consider the expressions "*to eat an apple*" and "*to eat an hour*" (for instance in: "*You may also need* to eat an hour *before training…*"): without a general culture which allows us to distinguish between food items and time intervals the correlation expressed in the previous sentences could not be correctly produced or interpreted.

As a consequence of this tight connection to knowledge and experience, language cannot merely be considered as a strictly organised and classified system of words and phrases: it must also be approached as an extremely intuitive arrangement of things, intuitive in its production and intuitive in its interpretation (Glasersfeld 1965, XIII–1). This is not to say that language does not include logical functions and logical implications, but it embraces very much more: for instance, interpretations that are "correct" merely because they are much more probable than others, given our experience of the world we live in and our knowledge of how certain things are related (notional sphere).

Conclusion

Since the great apes are the closest relatives to human beings, experiments in teaching them a language can shed some light on the human mind. Although Lana could not speak, she learned to communicate in the Yerkish language. Lana was the first ape to work with a computer keyboard, the first to show that chimpanzees could form syntactically correct sentences, could recognize written symbols, could read and could complete incomplete sentences appropriately. On many occasions within the context of the LANA project, by means of appropriate Yerkish sentences she made it quite clear that she was not only capable of forming concepts and of using lexigrams but also able to participate in a manner of living that we call language, i.e., that she could experience a recursive coordination of behavioural coordinations, through which she could recursively influence what she was experiencing.

The key question in her language acquisition is how Lana learned the appropriate syntactic forms and word order for expressing complex relations in Yerkish as well as a kind of common sense background knowledge. How did she correctly concatenate the lexigrams? How did she learn to do that? Was it merely due to good training practice on the part of the primatologists? Our hypothesis is that the success of Lana is primarily due to the fact that she learned the grammar rules of Yerkish. How? By matching her conceptual abilities with the correlational structure of Yerkish. As a consequence we see the success of Yerkish during the past decades (originally with Lana since 1973 and later with other apes, such as Kanzi) as a demonstration of the viability of the operational methodology that is its foundation. We hence propose that Lana's conceptual system be considered as a correlational system in which the operation of correlation is what constitutes the chimpanzee's thinking and an attentional system delivers the mental contents that correlation assembles into triads and networks. Since no other assessment or explanation of Lana's performances has considered these fundamental issues, we strongly suggest that a new research project or program be conducted to investigate the above-mentioned hypothesis of the importance of Yerkish in Lana's success in language learning.

Notes

1. Yerkes National Primate Research Center, http://www.yerkes.emory.edu/
2. Alan and Beatrice Gardner about Washoe: see Gardner, R.A. & Gardner, B.T. (1969) and (1971)
3. Piero Pisani, a computer scientist who had worked with von Glaserfeld in his automatic translations projects, first in Italy and later in USA.
4. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=Display&DB=pubmed
5. The Georgia State University Language Research Center, http://www2.gsu.edu/~wwwlrc/chimps.htm
6. "The Amazing Apes," a TV program produced in 1977 by Bill Burrud, which includes a six-minute feature on the chimpanzee Lana, seen during training sessions of the LANA project where Lana communicates via her keyboard with researcher Tim Gill. The movie can be viewed at http://www.greatapetrust.org/research/general/lana.php#
7. Also mentioned in Maturana and Varela (1987), pp. 215–217

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