YERKISH

A Visual Language for Computer-Mediated Communication by an Ape

Marco Cesare Bettoni(✉)

Steinbeis Center Knowledge Management and Collaboration, 4059 Basel, Switzerland
marco.bettoni@weknow.ch

Abstract. Yerkish is a visual language designed for exploring the extent to which great apes could be taught to acquire linguistic skills. This instrumental aspect of Yerkish as part of an experimental communication study had a strong influence on its design and must be kept in mind all times. For this reason, the *first* part of this paper briefly outlines the context in which the Yerkish language originated: the LANA research project (1970–1976). In the *second* part, the language itself is presented in more detail: first the main distinction between an ordinary and a "correlational" grammar like that of Yerkish, then its lexicon composed of graphic word symbols, so-called "lexigrams" and finally its grammar with examples of Yerkish sentences. We propose that the LANA project was successful because Yerkish grammar is fundamentally different from ordinary grammars; for this reason, the *third* 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 from which the term "correlational" was derived for distinguishing the grammar of Yerkish from other ordinary grammars.

Keywords: Correlational grammar · Operational methodology · Notional sphere

1 Introduction

Yerkish is a visual language developed and used from 1970 to 1976 in the context of the LANA project at the Yerkes Primate Research Center in Atlanta for investigating the abilities of great apes to communicate with humans by means of a language [1, 16–18]. Yerkish is named after Robert Yerkes, an American primatologist who, in 1930, had established the first National Primate Research Center in the USA. The basic ideas of the project were: a) to introduce a *computer* for monitoring, recording and reacting to all sentences formulated by the experimental animal, an infant female chimpanzee called Lana; b) to use a *visual* language, in view of the success of the Gardners with their chimpanzee Washoe, who had learned to communicate visually in American Sign Language [10]. The project was successful; Lana acquired linguistic competence (see the Appendix, Table 4) and the team "*felt that her identity was well worth preserving*" [23] so that the whole project was renamed after her - the "Lana Project".

M. M. Soares et al. (Eds.): HCII 2021, LNCS 12779, pp. 351–371, 2021.
https://doi.org/10.1007/978-3-030-78221-4_24

2 The Experimental Environment

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 *interaction board* used by Lana (keyboard, visual displays, dispensers, etc. see Fig. 1) whereas the computer itself and all its external components were placed just outside the cubicle [25].

Input to the computer was achieved by means of two keyboards (one for Lana and one for the experimenters), each arranged in panels of 25 keys. Four such panels were in use at the end of the project in 1976, corresponding to a total of 100 keys that Lana had learned to use.

Each key was labelled by means of abstract, geometrical designs: visual elements that von Glasersfeld called "lexigrams" [19] and developed as abstract graphic symbols to be used as words in the Yerkish language (Fig. 2). The lexigrams were obtained by combining 2, 3 or 4 simple graphic elements and one color selected from a set of only 9 basic design elements (Fig. 3) and 7 background colors.

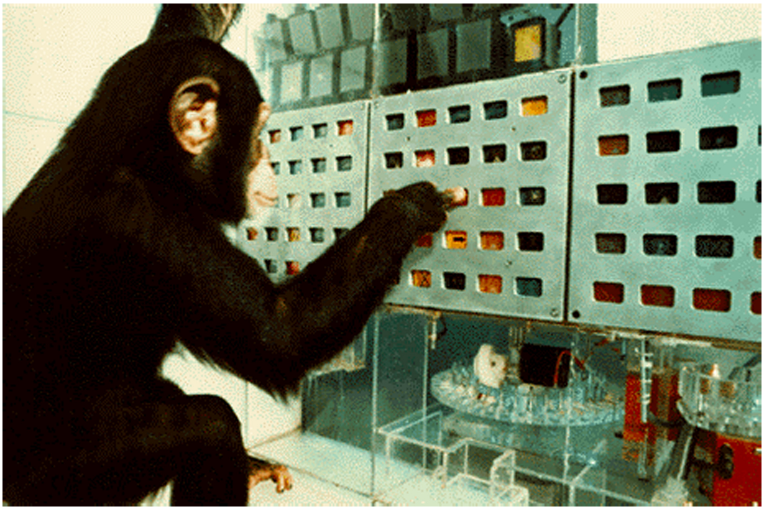

Fig. 1. The chimpanzee Lana working at her keyboard

Above the keyboard, in the experimental chamber, was a sturdy horizontal bar that Lana had to hang on to in order to switch on the system (Fig. 1). Directly above the keyboard there was also a row of visual displays, seven small projectors in which the lexigrams appeared one by one from left to right, as their keys were being pressed on the keyboard. This provided Lana with feedback concerning the part of the message she had already typed in, and also with a linear representation of the sentence she was composing. A signal light on the right of the projectors lit up when the "period" key was pressed and terminated the message (the "end-of-message" signal for the computer).

Thus, when several keys were pressed in succession, ending with the period key, the corresponding string was sent to the computer, which contained the vocabulary,

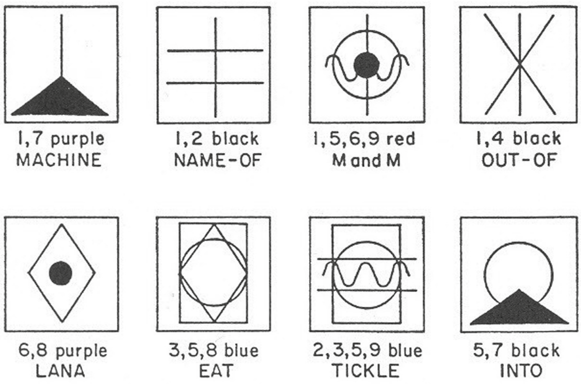

Fig. 2. Examples of lexigrams

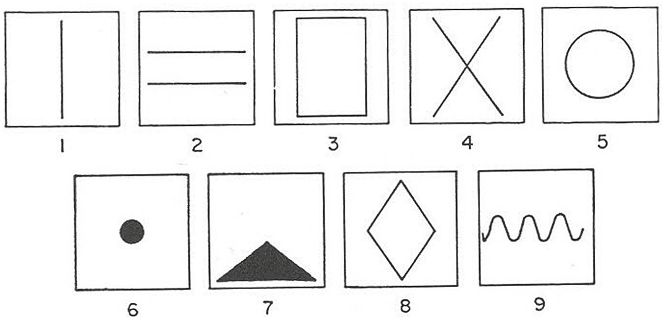

Fig. 3. Set of 9 basic design elements

the grammar of Yerkish, the automatic parser and the rules for activating a dispenser and other devices in response to the string Lana had produced. The parser took this string as a "sentence" and analyzed it to establish whether or not Lana had produced a grammatically correct sentence in terms of Yerkish grammar [16].

Below Lana's keyboard was the row of food and drink dispensers (vending devices), activated by the computer (Fig. 1); they provided all sorts of food and drink (like apple, bread, chow, banana, water, milk, juice etc.) and Lana learned to feed herself using Yerkish sentences typed on the keyboard. Besides providing food and drink, the computer could respond to requests correctly formulated in Yerkish by playing taped music or sounds, projecting movies and slides as well as opening and shutting a window.

Regardless of the outcome of the grammatical analysis, the system printed out the English word corresponding to each lexigram activated and recorded - at the end of the string - whether or not it was found to be correct. Messages originating from the researcher's keyboard were also recorded by the computer.

The computer itself (a PDP-8/E minicomputer from Digital Equipment Corporation), the terminal with a keyboard for the researchers, the printer and an auxiliary instrumentation rack were all placed just outside the experimental chamber in which Lana lived: from here, the experimenters could interact with Lana by typing sentences that were displayed above her keyboard, on a second row of projectors (similar to the first mentioned before) and they could also see how she was behaving during the computer-mediated communication session.

3 The Language

The grammar of Yerkish is a direct derivative of the "correlational" grammar implemented by von Glasersfeld in the Multistore parser for English sentences [1, 11–15].

A correlational grammar of this type is fundamentally different from an ordinary grammar. Due to misunderstandings that have haunted the development of correlational grammar since the beginning, I will dwell for a moment on the essential aspects that distinguish it from ordinary grammars.

3.1 Correlational Grammar

The correlational grammar of Yerkish is based on the theoretical framework of Operational Methodology conceived by Silvio Ceccato who used this approach for defining and implementing the first correlational grammar in the context of Mechanical Translation [4, 20]. This type of grammar is concerned with *interpreting* the content of a given piece of language in terms of a canonical form, composed of pre-established semantic elements or modules. It is an *interpretive* grammar in the sense that it consists of rules that govern this interpretation; these rules describe the language only indirectly, since what they actually describe is a *cognitive* model of the language user in the receiving role. Thus, while the term "grammar" is predominantly used to indicate the formalized description of a language, e.g. Chomsky [9], a "correlational grammar" is, instead, the description of an *interpretive system.*

The main difference from ordinary grammars consists of shifting of focus from characteristics of words and sentences, qua *linguistic* items, to the characteristics of concepts and conceptual structures, qua *cognitive* items. A parser that is intended to extract the conceptual content from pieces of language must be able to identify not only the conceptual items involved, but also the relational concepts by means of which they are connected with one another. The linguistic expressions for those relational concepts (connectives) that link items on the conceptual level were called "correlators" by Ceccato, and he therefore spoke of a "correlational grammar" for his approach.

3.2 Constraints

Because Yerkish had to be an instrument of an experimental animal communication study, its design was subject to research and budget constraints that were specific to the Lana project (see Sects. 1 and 2).

There were essentially three *animal research* constraints:

1. Drawing on the experience with the chimpanzee Washoe, who had learned to communicate visually in ASL (see Sect. 1), Yerkish had to be a *visual* language with a lexicon of unitary word-symbols that could be represented singly on the keys of a keyboard.
2. In order to make the acquisition of the language easier for Lana, both lexical items and sentence structure were to be as *univocal* as possible.
3. In order to make participation in communication events, as well as their evaluation, as accessible as possible to researchers and observers, the structure of Yerkish was to be close enough to English to allow word-by-word translation.

Budget restrictions due to limited project funding caused additional constraints:

- The lexigrams of Yerkish had to be such that the feedback projectors above the keyboard could be all of one single type, able to display all the lexigrams. This is why the lexigrams were designed from a set of only 9 basic design elements (Fig. 3) and 7 background colors.
- The size of the PDP-8/E computer limited the universe of discourse of Yerkish to a maximum of 250 lexigrams, 46 lexigram classes and 46 lexigram connectives (correlators, see next, Sect. 3.5).
- The size of the computer's workspace also limited the real-time processing of a given sentence during computer-mediated communication. The computer resources needed for this processing depend on the number of the lexigrams from which the string is composed; thus, in order to be on the safe side (use less computer workspace than available), the sentence length was initially limited to 7 lexigrams. Later experience showed that the PDP-8/E could handle up to 10 lexigrams and plans were made to increase the sentence length accordingly.

3.3 Essential Characteristics of Language

Language as a communicatory system has three indispensable characteristics [17]: 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*. Due to the above-mentioned shift in Yerkish from the linguistic to the cognitive perspective, the following description of its lexicon and grammar will be more intertwined (in particularly with semantics) than in an ordinary grammar.

3.4 Lexicon

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 during the project. There were about 150 words in this preliminary vocabulary. After compiling the lexicon of Yerkish, the lexical items were divided into classes (see Table 1). This classification is determined by the relational characteristics of the conceptual items and specifies the potential of each item for entering into structural relations with the members of the other classes (for situational representations); during the process of interpretation, the *linguistic* structures of the input (like phrases and sentences) will then be connected with the *conceptual* structures that the lexigram classification makes possible (semantic connection).

In fact, since Yerkish was designed based on a "correlational" approach to language [15], the lexigram-classes were defined in terms of cognition (functional, conceptual characteristics of the associated concepts) and not, like in an ordinary descriptive grammar, in terms of language form (morphology and the formal roles that words play in sentences, like noun, verb, adjective, etc.). Thus, the lexigram classes contained in the lexicon specify the *semantic* connections between elements at the linguistic level and elements at the conceptual level.

In the case of "things" this is, for instance, the kinds of activity which they can perform as *actors* and the kinds of activity in which they can play the role of *patient*; and in the case of "activities" it is, for instance, the kinds of *change* they bring about. Thus, items associated with concepts 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-classes: "familiar primates" (lexigram Lana and lexigrams for the first names of technicians and experimenters, like Tim or Shelley), "unfamiliar primates" (lexigram visitor), "non primates" (lexigram roach) and "inanimate actor" (lexigram machine).

In the case of items that can be eaten and items that can be drunk, the lexigrams designating them were divided into "Edibles", i.e. suitable patient/objects like bread or raisin for the activity designated by EAT and "Drinkables", i.e. suitable patient/objects like water and milk for the activity designated by DRINK. Together they constituted the lexigram *general type* of "Ingestibles" which was marked on the keyboard by a red background of the corresponding lexigrams (see Table 2).

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).

3.5 Grammar

Like the lexicon, the grammar of Yerkish is also "correlational" and hence interpretive in the sense previously explained. Any lexigram sequence that the parser can *interpret* by means of the rules of its primitive syntax is to be considered correct whereas any input that it cannot is to be considered mistaken.

Yerkish has three classes of sentences: statements, requests, and questions. Requests are differentiated from the others by first pressing a key called "please"; questions have to begin with a question mark.

The correlational approach to language is based on the assumption that sentences express, at the language level, sequences of mental operations (attentional operations) performed at the cognitive level [5]. The most important of the mental operations are obviously those that establish connections among conceptual items (operands) and in doing so, build up complex structures. These relational concepts, that Ceccato called *correlators* [4], are connective functions used at the mental level during the process of correlating. In natural languages, correlators are indicated using a variety of means, either implicitly or explicitly.

A correlator is always a binary function in that it links two mental operands, two concepts - the left-hand correlatum LH and the right-hand correlatum RH - and thus forms a new unit (a triad) called a "correlation". 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 (like propositions, conjunctions, etc.). In the following, we will use "correlator" both for the relational concepts and for the linguistic devices that express them (Fig. 4).

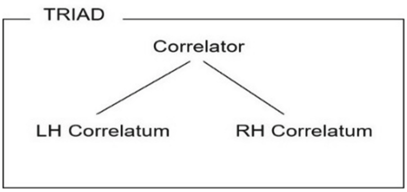

Fig. 4. A correlator (triad) as a binary function

In 1975, the Yerkish grammar used by Lana operated with the correlators listed in Table 3 "Operational Correlators" (see the Appendix). In this table, each correlator is specified by 3 attributes: 1) an ID number for the correlators, 2) lexigram classes or sub-classes for the LH correlatum, 3) lexigram classes or sub-classes for the RH correlatum.

First-Level Correlations – Example A
To give an example, consider correlator No. 11:

- at the *cognitive* level, this correlator can be paraphrased as: "stationary activity (ingestion of solids) involving edibles (solid food stuff)"; it connects a concept of the lexigram class VE with a concept of the lexigram sub-classes EU or EM (Fig. 5);
- at the *linguistic* level, in the lexigram class VE there is only one lexigram, EAT (Table 1), hence: *LH correlatum* = *EAT*; instead, in the lexigram class Edibles, we can choose from 2 sub-classes with a total of 7 lexigrams, for instance: *RH correlatum* = *RAISIN*; finally, for the correlator itself, there is no explicit lexigram, it is an *implicit correlator*, expressed merely by the juxtaposition of the two lexigrams (Fig. 6).

Since the order of succession of the two items in the linear linguistic expression is obligatory (cannot be reversed), it is not enough for the grammar merely to supply the information that correlator No. 11 can link the lexigrams EAT and RAISIN; the grammar must also specify that, in this correlation, EAT has to be the left-hand piece (LH) and RAISIN the right-hand piece (RH). This information is part of the permanent lexicon of the system. It is recorded here by means of "correlation indices" (Ic's), which consist of

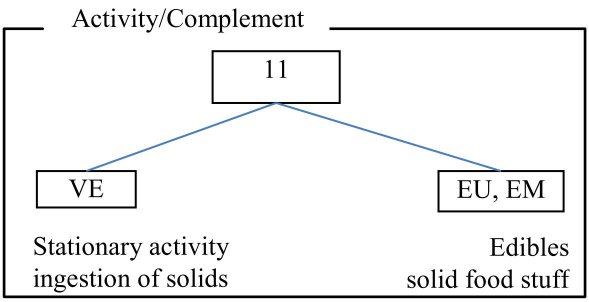

Fig. 5. Correlator 11, *cognitive* level

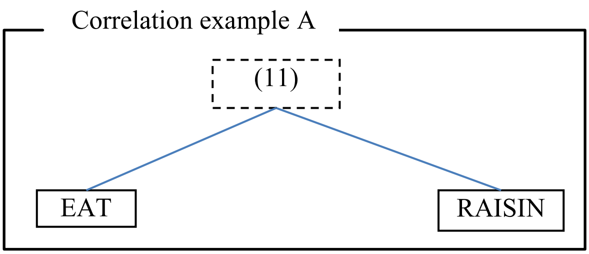

Fig. 6. Correlator 11, *linguistic* level: "EAT RAISIN"

the ID number of the potential correlator plus the indication as to whether the items to which this Ic is assigned can function as a LH-piece or as RH-piece.

First-Level Correlations: Example B

To expand on the example above, let us consider a correlation with correlator No. 01:

- at the cognitive level, this correlator can be paraphrased as: "autonomous animate actor performing stationary activity", where "stationary activity" means activities that do not involve a change of place on the part of the actor, nor a change of hands on the part of a patient. This correlator can connect a concept of the sub-classes AP ("familiar primates", i.e., the researchers), AV ("visiting primates", i.e., unnamed human or non-human visitors) or AO ("non-primates") with a concept of the sub-classes VE ("ingestion of solids"), VD ("ingestion of liquids") or VA ("relational motor act").
- at the *linguistic* level, in the three lexigram sub-classes AP, AV and AO, we can choose among 7 lexigrams, for instance: *LH correlatum* = *LANA*; and also, in the three sub-classes VE, VD and VA, we can choose from 7 lexigrams, for instance: *RH correlatum* = *EAT*. Finally, like in the previous example, for the correlator itself there is no explicit lexigram (Figs. 7 and 8).

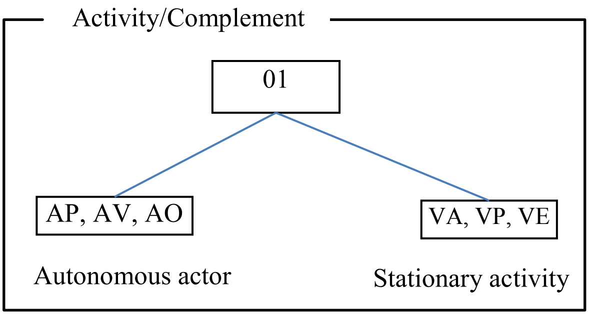

Fig. 7. Correlator 01, *cognitive* level

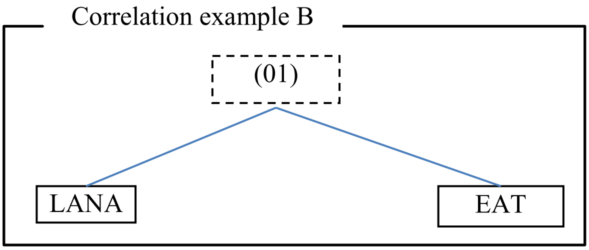

Fig. 8. Correlator 01, *linguistic* level: LANA EAT

Correlational Products and Matrix

Given the lexigram sequence LANA EAT of example B, the interpretive grammar finds that lexigram LANA, belonging to class AP, bears the Ic [01, LH], while lexigram EAT, belonging to class VE, bears the Ic [01, RH]. On the strength of this, the grammar will allow the correlation "LANA EAT" with correlator No. 01.

For the parser, "allowing a correlation" means recording it as a possible part-interpretation of the input string. As such, it is recorded as a *product* P in order to be tested for its potential correlability with other parts of the input.

The information on the basis of which first-level correlations are formed (connecting single lexigrams as in correlation example A and B) constitutes a *matrix of correlational indices* which, in the computer, is stored as part of the permanent lexicon (see Fig. 9). In this matrix, the correlational data required to form the examples A and B are represented by markers (x) at the *intersection* of a column with a row; thus, the Ic's are obtained by combining the LH or RH correlatum found at the head of the marked *column* with the lexigram class found at the beginning of the marked *row*. In 1975, the implementation of Yerkish grammar had n = 34 correlators and m = 35 lexigram classes, corresponding to a matrix of 2380 correlation indices [16].

Higher-Level Correlations: Example C

If the input string contains a higher-level structure, for instance a phrase obtained by adding a lexigram to already correlated lexigrams, like in "LANA EAT RAISIN" (example A + example B), then the parser of Yerkish, in order to be able to handle this in

Lexigram Class	Correlators									
	01		02			11			n	
	LH	RH	LH	RH	………	LH	RH	………………..	LH	RH
AP	x									
AO	x									
. . . .										
EU							x			
. . . .										
VE		x				x				
. . . . m										

Fig. 9. Matrix of correlation indices

exactly the same way as single lexical items, assigns a set of Ic's to each product P that represents its particular potential for functioning as a component (LH-piece or RH-piece) of a new and larger correlation that links it with other lexical items or phrases.

The procedure that assigns these Ic's to a given product is what might be called the dynamic part of the grammar.

In case of "LANA EAT RAISIN", the parser assigns the Ic [01 RH] to the phrase "EAT RAISIN" (Fig. 10). In order to do this, there has to be an operational assignation rule that makes sure that a *first-level correlation* produced by correlator No. 11 (we call this product P11) is assigned the Ic [01, RH] so that it can be linked in a *second-level correlation* with the preceding lexigram LANA, which bears the Ic [01, LH].

But this assignation must be made contingent upon the condition that the product P11 does, in fact, contain a lexical item of sub-class VE, VD or VA as a LH-piece; because only if P11 contains a member of the class "Stationary Activities" can it function as an activity of the actor designated by the LH lexigram LANA.

Higher-Level Correlations: Example D

Yerkish structures can, of course, have more than two levels. Here is an example of a Yerkish sentence with 5 correlational levels which, in English, would read: "Is there no piece of apple here?" [16] (Fig. 11):

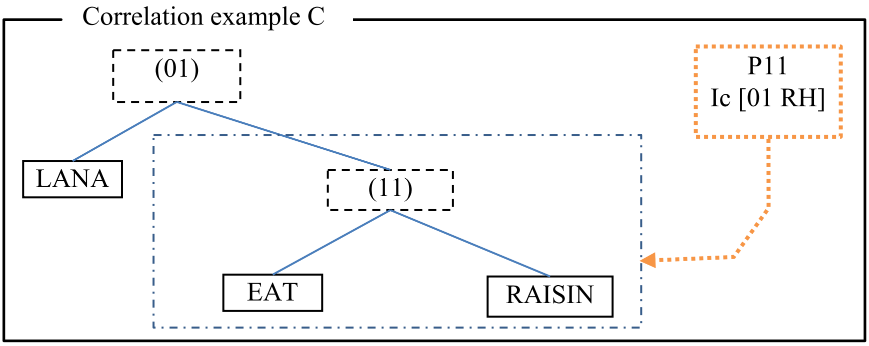

Fig. 10. Higher-level correlation 01 + 11: LANA EAT RAISIN

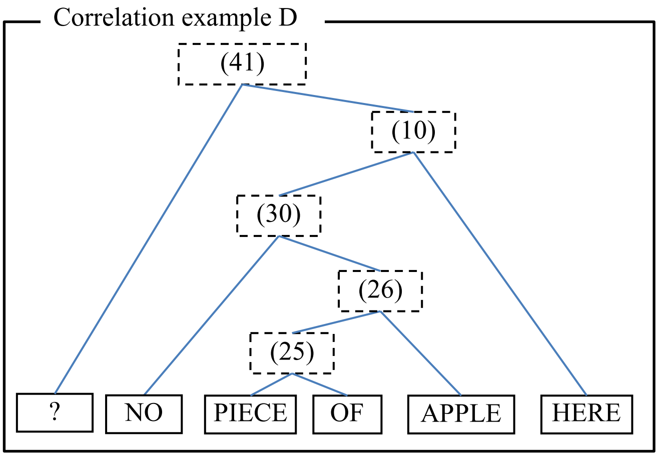

Fig. 11. Correlational network (binary tree) with 5 levels and 5 correlators

4 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 [6]. Together with a group of scholars living in Italy, he proposed from the beginning to study thought and its contents in terms of operations [2, 3]. Because of this "operational approach" or "operational methodology," Ceccato's group was called the "Italian Operational School" (in Italian: *Scuola Operativa Italiana*).

His research activity was devoted to understanding the basic structure and dynamics of thought production, the development of an operational solution to the problem of semantics (connection of thought and language) and 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 the functioning of other organs into discrete pieces (so-called "praesentiata" or recepts) and builds an oscillation similar to alpha waves in the brain or to the rhythmic contractions of the heart. This conception of pulsating attention and of *discrete microunits of mental activity* has been confirmed by neurophysiological experiments suggesting that "*the seemingly continuous stream of consciousness consists of separable building blocks*" [21, 22].

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 also 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 are 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* was allocated 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 composed only of 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 *correlation* 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 [4, 7]. 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 correlate* in another correlation, which in its turn can become a piece 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.

5 Language and Thought

A fundamental function of language consists of 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 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!

Ordinary 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 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., 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 characterization 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 a correlatum or correlator within a correlation [13].

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 the correlation (correlational function), whether that of correlator or that of the first (left hand) or second (right hand) correlatum. In order to supply these indications, languages can basically offer 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 (3 for the items and 3 for their place in the correlation) 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 means that 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 designation of one of the correlates but in all other cases, indication of the appropriate correlator has to be deduced from a widespread knowledge and a common cultural heritage behind any language, for which Ceccato has coined the terms "Notional Sphere" and "Constellation" [4], which were precursors to methods of knowledge representation such as frames and scripts in early Artificial Intelligence research [24].

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 [8]. 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 close connection to knowledge and experience, language cannot merely be considered as a strictly organized 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 [12].

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 in which we live and our knowledge of how certain things are related (notional sphere).

6 Conclusion

Lana learned to communicate successfully in Yerkish. She was the first ape to work with a computer keyboard and the first to show that chimpanzees could form syntactically correct sentences, recognize abstract written symbols, read and complete incomplete sentences appropriately. On many occasions, using appropriate Yerkish sentences, Lana 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 behavioral coordinations, through which she could recursively influence what she was experiencing (see Table 4). How did Lana 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? My hypothesis is that the success of Lana is primarily down to the fact that Yerkish enabled her to learn the grammar rules in a suitable way. In which sense suitable? In the sense that the correlational structure of Yerkish matched her conceptual abilities. As a consequence, I see the success of Yerkish in the Lana project as a demonstration of the viability of Silvio Ceccato's Operational Methodology that forms its theoretical foundation.

Appendix

- Table 1. Operational Lexigram Classes

Table 1. Operational Lexigram Classes [16]

Lexigram class	Abb.	English translation of lexigrams	Comments
Autonomous Actors	AP	BEVERLY, SHELLEY, TIM, LANA	Familiar primate (human and non-human)
	AV	VISITOR	Unfamiliar primate
	AO	ROACH	Non-primates
	AM	MACHINE	Inanimate actor
Absolute Fixtures	FA	FLOOR, KEYBOARD, ROOM	Items that cannot move or be moved
Relative Fixtures	FF	DOOR, PUSH-KEY (push-button), WINDOW	Items that can move but not change place
Transferables	TF	BALL, BLANKET, BOWL, BOX, BUCKET, DOLL, PLATE, STICK	Items that can change place and/or hands
Edibles	EU	M&M (candy), RAISIN	Dispensed as unit
	EM	APPLE, BANANA, BREAD, CHEW, COOKIE	Dispensed in pieces
Drinkables	ED	COKE, JUICE, MILK, WATER	
Parts of Body	PB	BACK, EAR, EYE, FINGER, FOOT, HAND, HEAD, MOUTH, TUMMY	Can change place but not hands
States, conditions and categories			
Colors, touch, etc.	ST	BLACK, BLUE, GREEN, ORANGE, PURPLE, RED, WHITE, YELLOW, DRY, WET, HARD, SOFT, COLD, HOT, OPEN, SHUT, CLEAN, DIRTY	As attributed to items
Locational	LS	AWAY, DOWN, HERE, UP	As attributed to items
Ambiental Conditions	CD	COLD n., DARKNESS, HEAT, LIGHT n., MOVIE, MUSIC, SLIDE n., VOICE	Sights, sounds, smells, etc. are treated as states of the environment that can be caused (MAKE) by an agent

(*continued*)

Table 1. (*continued*)

Lexigram class	Abb.	English translation of lexigrams	Comments
Conceptual Categories	CT	BEGINNING, BOTTOM, COLOR, CORNER, END, PIECE, SIDE, TOP	As applied to spatio-temporal items
Activities			
Stationary	VE	EAT	Ingestion of solids
	VD	DRINK	Ingestion of liquids
	VA	BITE, GROOM, HIT, HOLD, TICKLE	Relational motor act
Locomotive	VB	CARRY	Transferring (place change)
	VC	PULL, PUSH	Requiring contact and force
	VG	BRING, GIVE	Causing change of hands
	VL	MOVE, SWING, TURN	Change of place
Stative	VS	LIE, SLEEP, STAND	Maintaining position in place
Conceptual	VM	MAKE	Causative, creating change
	VP	SEE	Perceptual activity
	VW	WANT	Conative activity
Prepositions			
Locational	LP	IN, ON, OUTSIDE, UNDER	
Directional	DP	BEHIND, FROM, INTO, OUT-OF, THROUGH, TO, TO-UNDER	
Partitive	PP	OF	
Determiners & Markers			
Determiners	DD	THIS, THAT	Demonstrative
	DQ	ALL, MANY, NO (not one), ONE	Quantitative
	DC	LESS, MORE	Comparative
Semantic	NF	NAME-OF	Indicating semantic nexus
Identity-Difference	ID	SAME-AS, OTHER-THAN	
Attributive	WR	WHICH-IS	Also relative clause marker
Sentential		PLEASE	Request (imperative)
		"?"	Query (Interrogative)
		NOT	Negation
		YES	Affirmation
		"." (period)	End-of-message marker

- Table 2. Semantic Color-Coding of Lexigrams

Table 2. Semantic Color-Coding of Lexigrams [16]

Color	General Type	Lexigram classes (abb.)
Violet	Autonomous Actor	AP, AV, AO, AM
Orange	Spatial Objects, Spatial Concepts	FA, FP, TF, CT, WP
Red	Ingestibles	EU, EM, ED
Green	Parts of Body	PB
Blue-Grey	States and Conditions	ST, LS, CD
Blue	Activities	VA, VB, VC, VD, VE, VG, VL, VM, VP, VS, VW
Black	Prepositions, Determiners, Particles	DC, DD, DO, DP, LP, ID, NF, PP
White (+)	Affirmation	"YES"
Yellow (+)	Sentential Modifiers	Query, Please, Negation, Period

- Table 3. Operational Correlators connecting lexigram classes and sub-classes

Table 3. Operational Correlators connecting lexigram classes and sub-classes [16].

LH Correlatum lexigram class & sub-classes	Correlator ID	RH Correlatum lexigram class & sub-classes
Actor/Activity		
Autonomous actor AP, AV, AO	01	stationary activity VA, VP, VE
Autonomous actor AP, AV, AO	02	transferring activity VB
Autonomous actor AP, AV, AO	03	act. requiring contact and force VC
Autonomous actor AP, AV, AO	04	perceptual activity VP
Autonomous actor AP, AV, AN	05	causing change of hands VG
Causative agent AP, AV, AM	06	causing change of state VM
Actor AP, AV, A0, FP, TF, EU, PB	07	change of place VL
Item capable of changing location AP, AV, AO, FP, TF, EU, EM, ED, PB	08	stative activity VS
Conative agent AP, AO, AV	09	conative activity VW

(*continued*)

Table 3. (*continued*)

LH Correlatum lexigram class & sub-classes	Correlator ID	RH Correlatum lexigram class & sub-classes
Predicative Copula		
Item with perceptual characteristics AP, AV, AO, FA, FP, TF, EU, EM, ED, PB, CD, WR	10	predicated state ST, LS
Activity/Complement		
Ingestion of solids VE	11	solid food stuff (as patient) EU, EM
Ingestion of liquids VD	12	ED liquid (as patient)
Stationary motor activity VA	13	any spatial item (as patient) AP, AV, AO, FA, FP, TF, EU, ED, PB
Transferring VB	14	item capable of change of place AP, AV, AO, TF, EU, ED, PB
Contact and force VC	15	any spatial item (as patient) (same as for 13!)
Perceptual activity VP	16	any perceptual item (as result) AP, AV, AO, FA, FP, TF, EU, EM, ED, PB, CD
Change of hands VG	17	handable item (as patient) AO, TF, EU, ED
Causing change VM	18	CD, CS condition or state
Conative activity VW	19	desired item (as result) AO, TF, EU, ED, CD, VE, VD, VS
Activity/Spatial Adjunct		
Change of place VC, VL (and P's: 14,15,17)	21	target location LS (and P's: 22)
Directional preposition DP	22	specification of target AP, AV, AO, FA, FP, TF, EU, EM, ED, PB
Stative activity localization VS, (and P's 11, 12, 13)	23	specification of location LS (and P's 24)
Locational preposition LP	24	specification of location (same as for 22!)
Relation Whole/Part		
Item considered "part" PB, CT	25	PP partitive preposition
Item considered "part" P's: 25	26	item considered "whole" AP, AV, AO, FP, TF, EU, EM, ED, PB, DD
Naming Function		
Semantic indication NF	27	AV, DD item to be named
New lexigram or WHAT	28	item designated

(*continued*)

Table 3. (*continued*)

LH Correlatum lexigram class & sub-classes	Correlator ID	RH Correlatum lexigram class & sub-classes
Conceptual Categorization		
Determiner DO, DC, DD	30	any item singled out AP, AV, AO, FA, FP, TF, ED, EU, EM, PB, CD, CT
Relative Clause		
Item to be qualified AP, AV, AO, FA, FP, TF, EU, EM, ED, PB, CD	31	restrictive marker WHICH-IS (WR)
Comparative State		
Quantitative determiner DQ	32	ST, LS, LP, DP state
Identity Function		
Identify-difference marker ID	33	term of comparison AF, AV, AO, FA, FP, TF, EU, EM, EU, PB, CD, DD
Sentence Modifiers		
Request marker PLEASE	40	expression turned into request
Question marker QUERY	41	expression turned into question
Negation marker NOT	46	expression negated

- Table 4. Yerkish conversation with Lana recorded on May 6th, 1974

Table 4. Yerkish conversation with Lana recorded on May 6th, 1974 [16]

On the preceding days, Lana had learned the lexigrams for a bowl and a metal can, BOWL and CAN. This had been accomplished by first using objects whose names were already known to her, putting an M&M candy inside them, and asking her: ? WHAT NAME-OF THIS On May 5th she reliably replied with the correct lexigram when the reward was placed in the bowl or in the can. The next morning Tim (Timothy V. Gill, a primatologist, member of the project team) came in with the bowl, the can, and a cardboard box. While Lana was watching, he put an M&M candy in the box, and the following exchange took place in Yerkish:	
Lana	? TIM GIVE LANA THIS CAN
Tim	YES
-	*Tim gives her the empty can, which she at once discards*
Lana	? TIM GIVE LANA THIS CAN
Tim	NO CAN
Lana	? TIM GIVE LANA THIS BOWL

(*continued*)

Table 4. (*continued*)

Tim	YES
	Tim gives her the empty bowl
Lana	? SHELLEY - (*Sentence unfinished*)
Tim	NO SHELLEY
-	*Shelley, another team member who worked with Lana, is not present*
Lana	? TIM GIVE LANA THIS BOWL
	Before Tim can answer, Lana goes on
Lana	? TIM GIVE LANA NAME-OF THIS
	A spontaneous generalization of GIVE, not foreseen by the grammar of Yerkish, since NAME-OF had not been classified as a possible object of GIVE!
Tim	BOX NAME-OF THIS
Lana	YES (*Short pause, and then*) ? TIM GIVE LANA THIS BOX
	Tim gives it to her, she rips it open and eats the M&M

References

1. Bettoni, M.: The Yerkish language - from operational methodology to Chimpanzee communication. Constr. Found. **2**(2), 32–38 (2007). Festschrift in honor of Ernst von Glasersfeld
2. Ceccato, S.: Language and the table of Ceccatieff. Hermann & Cie, Paris (1951)
3. Ceccato, S.: Consapevolizzazione dell'Osservare, mod. 3", Atti del Congresso di Metodologia. Ramella, Torino (1953)
4. Ceccato, S., et al.: Linguistic Analysis and Programming for Mechanical Translation. Feltrinelli: Milan/Gordon & Breach, New York (1960/1961)
5. Ceccato, S.: A model of the mind. Methodos **16**, 3–78 (1964)
6. Ceccato, S.: Un tecnico fra i filosofi, vol. 1 & 2. Marsilio, Padova (1964/1966)
7. Ceccato, S.: Correlational analysis and mechanical translation (1967). Reprinted in: Nirenburg, S., Somers, H., Wilks Y. (eds.): Readings in Machine Translation. MIT Press, Cambridge (2003)
8. Ceccato, S., Zonta, B.: Linguaggio, Consapevolezza, Pensiero. Feltrinelli, Milan (1980)
9. Chomsky, N.: Aspects of the Theory of Syntax. M.I.T. Press, Cambridge (1965)
10. Gardner, R.A., Gardner, B.T.: Teaching sign language to a chimpanzee. Science **165**, 664–672 (1969)
11. von Glasersfeld, E.: Multistore - a procedure for correlational analysis. Automazione, e Automatismi **9**, 2 (1964)
12. von Glasersfeld, E.: An approach to the semantics of propositions. In: Proceedings of the Conference on Computer-Related Semantic Analysis, Las Vegas, USA, 3–5 December 1965, pp. XIII 1–24. National Science Foundation & Office of Naval Research, U.S. Air Force (1965)

13. von Glasersfeld, E., Pisani, P.P.: The Multistore System MP-2, Scientific Progress Report. Georgia Institute for Research, Athens, Georgia (1968)
14. von Glasersfeld, E., Pisani, P.P.: The Multistore parser for hierarchical syntactic structures. Commun. Assoc. Comput. Mach. **13**(2), 74–82 (1970)
15. von Glasersfeld, E.: The correlational approach to language. Thought Lang. Oper. **1**(4), 391–398 (1970)
16. von Glasersfeld, E.: The Yerkish language for non-human primates. Am. J. Comput. Linguist. **1**(3), 1–55 (1974)
17. von Glasersfeld, E.: Linguistic communication: theory and definition. In: Rumbaugh, D.M. (ed.) Language Learning by a Chimpanzee: The LANA Project, pp. 55–71. Academic Press, New York (1977a)
18. von Glasersfeld, E.: The Yerkish language and its automatic parser. In: Rumbaugh, D.M. (ed.) Language Learning by a Chimpanzee: The LANA Project, pp. 91–129. Academic Press, New York (1977b)
19. von Glasersfeld, E.: Radical Constructivism: A Way of Knowing and Learning. Falmer Press, London (1995)
20. Hutchins, J. (ed.): Early Years in Machine Translation. John Benjamins, Amsterdam (2000)
21. Lehmann, D., Strik, W.K., Henggeler, B., Koenig, T., Koukkou, M.: Brain electric microstates and momentary conscious mind states as building blocks of spontaneous thinking: I. Visual Imagery and abstract thoughts. Int. J. Psychophysiol. **29**, 1–11 (1998)
22. Lehmann, D., Koenig, T., Pascual-Marqui, R.D., Koukkou, M., Strik, W.K.: Functional tomography of EEG microstates of visual imagery and abstract thought: building blocks of conscious experience. Brain Topogr. **12**, 298 (2000)
23. Rumbaugh, D.M. (ed.): Language Learning by a Chimpanzee: The LANA Project. Academic Press, New York (1977)
24. Sowa, J.: Conceptual Structures. Information Processing in Mind and Machine. Addison-Wesley, Reading (1984)
25. Warner, H., Bell, C.L.: The system: design and operation. In: Rumbaugh, D.M. (ed.) Language Learning by a Chimpanzee: The LANA Project, pp. 143–155. Academic Press, New York (1977)