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Silvio Ceccato and the Correlational Grammar

Foreword

When I accepted the invitation to recount some memories of the work of my recently deceased friend Silvio Ceccato, I was aware of the risk inherent in writing about a highly technical field with which one has had no contact for three decades. Both Ceccato's and my involvement in machine translation was intense, but after it ended, neither of us had any further contact with that area of research. What I say here, therefore, is only as accurate as my memory.

I met Silvio Ceccato in the summer of 1947 on the shores of Lake Garda in Northern Italy. He had just written the introduction to the Italian translation of Wittgenstein's *Tractatus Logico-Philosophicus,* a book that before the war had engendered my lasting interest in epistemology and language. Ceccato's knowledge in that area was vastly superior to mine. He had spent a decade and a half reading everything in the field that he could get hold of, whereas my eclectic background contained nothing beyond Wittgenstein, Berkeley, and the "New Science" by Vico. Nevertheless our first conversation immediately made us aware of the general similarity of our philosophical orientation and led to a life-long friendship in which he was for many years my mentor and teacher.

He invited me to join the group of friends with whom he met, two or three times a year for a few days to discuss esthetics, the theory of knowledge, and language. Early on, they had all become dissatisfied with the traditional approach to these problems and were trying to formulate a "new way". The direction they were taking was based on the work of Percy Bridgman (1927; 1936) and when they published articles in journals, they called themselves the Italian Operational School.

In the United States, Bridgman's "Operationism" was adopted by the behaviorists, who naturally focused on the idea that concepts could be defined by the sequence of physical operations that constituted them. This reduced their Operationism to observable operations. In Europe, Bridgman's notion that general, "non-physical" concepts could also be operationally defined, but by mental rather than physical operations, was adopted by philosophers such as Hugo Dingler, and Ceccato saw in it a powerful tool to revolutionize the field of semantics.

Linguists who were dealing with the meaning of words and larger chunks of language, always confined their efforts to definitions in terms of other words. Ceccato, who thought of himself as a *Technician among philosophers* (the title of a two-volume work, 1962/1964), maintained that in order to *mechanize* linguistic processes, it was essential to define meanings in terms of repeatable and thus "controllable" mental operations that could be said to generate the things we talk about. His readings in philosophy had convinced him that these things were under all circumstances an observer's constructs and not, as the traditional theory of reference held, things of the "real" world.

In 1949 he founded the multilingual journal *Methodos,* for which for some years I did the translations into English to assure international readability. The journal lived for fifteen years and later, when I moved to the United States, I discovered that some libraries had indeed taken out subscriptions.[1]

MT Research at the Milan Center for Cybernetics

Early in the 1950s, Colin Cherry convinced Ceccato to explore the possibilities of applying the operational approach in the then topical field of machine translation. This led to Ceccato's contribution to the *Third London Symposium of Information Theory* and eventually to the beginning of research on MT at the University of Milan.

A proposal was submitted to the Rome Air Development Command of the US Air Force and its acceptance provided Ceccato for the first time with funds to hire a team of researchers. The Center of Cybernetics and Linguistic Research was created within the framework of the University of Milan, and in February 1959 it started to work on the mechanization of Russian/English translation under a two-year research contract from the US Air Force that was then extended for a second period of two years.

The basic presuppositions of the system, that was far from complete at the time and subject to continual modification, were four:

1. As the philosopher Giambattista Vico (1744) had suggested, there had to be a universal domain of human mental functioning that made it possible to translate from one language to another.

2. The operations that constitute this human universal are non-linguistic and their products form the substrate of "meaning" that is designated by different linguistic means in different languages according to their individual semantic and syntactic conventions.

3. Syntax, as the collection of relations that connect words with one another to form sentences, cannot adequately be described in separation from semantics and there are consequently many more "syntactic" relations than traditional grammars admit.

4. Satisfactory translation can take place only if a sufficient representation of the designated mental operations is derived from the input text and then transformed into an output according to the rules governing designation in the second language.

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1 Felice Accame, a student of Ceccato's, revived the journal under the name *Methodologia* some ten years ago and it is now available on the Internet (e-mail: methodologia@dellacosta.com)

As point 4 indicates, the representation of the specific concatenation underlying the input, in other words its conceptual *meaning,* is not a linguistic entity but a network of mental operations. However, as there was no model of a mechanism able to perceive, generalize, abstract, infer, hypothesize and attribute values to the items it produces, a vocabulary had to be invented to characterize the mental operations that were considered relevant.[2]

A Syntax of Mental Relations

At the time of the Milan research, other MT projects still clung to the early notion that syntactic structures of one language could be substituted for those of another, if only one elaborated complex enough formal transformation rules[3] . But the concept of an "interlingua" was gaining popularity. Though our approach could be put into this category, it is important to stress that in Ceccato's system the level presumed common to all languages did not consist of linguistic elements. The mental operations of which it was supposed to consist, of course, had to be *described* in a language such as Italian or English. It was no doubt this fact that led some critics to assert that Ceccato was merely re-inventing the basic categories of language (e.g. Mounin, quoted in Hutchins, 1986).

The most important among the mental operations were obviously those that established connections. The first job, therefore, was to isolate and describe the connective operations, and Ceccato called them "correlators". The second even more laborious task was to identify their linguistic markers.

We therefore spoke of *correlational nets* and a *correlational grammar*. In the languages we had examined (English, Russian, Italian, German, French, and Latin), correlators were indicated in two ways, either by specific words or by word-order. The first kind we called "explicit", the second "implicit". It would have been wiser to call the second "correlator expressions", to make clear that they were *linguistic* indicators of non-linguistic relational operations. But we went on referring to the linguistic expressions as correlators and prepared a comprehensive listing of them that we called *cartellone* or Master Table. In the explicit list, were all prepositions, conjunctions (some odd ones, such as "times" indicating a multiplicatory relation), and the words that specify intersentential links. The total amounted to a little over one hundred each, in the modern languages we examined. The initial lists of implicit correlator expressions contained some hundred items, but many of them were classes, some of them suggested by traditional grammar (e.g. subject/verb, verb/object, adjective/noun, etc.), and it was clear that the total number would be increased as the analysis of connective relations advanced.[4]

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2 An extensive description of the theoretical background can be found in the final report on the first two years of the project, *Mechanical translation: The correlational approach.* Milan: Feltrinelli, 1960; New York: Gordon and Breach, 1961.

3 In Victor Yngve's project at MIT, for instance, they were called "Structure Transfer Rules" (Yngve, 1965, p.9)

4 In my continuation of the research a few years later, we operated with some 300 correlators altogether, many of which were "double" in that they could handle the reverse order of the items to be connected.

The Planned Computer System

The machine procedure was to begin with the word for word input of a sentence. Each word called up a pre-established matrix that contained the indices of the conceptual relations the individual word-meaning could enter into with the meanings of the words that followed. Such combinations as were possible in the input sentence, created a new matrix and were automatically assigned ("reclassification") a set of correlational indices to enable their correlation with other words or word combinations. An intermediary output of the system was a graphic representation of correlational "nets" that comprised all the words of the input sentence and specified the underlying conceptual relations that connected them. A second procedure then converted the found relational net into correlations to be expressed in the output language and finally inserted the required output words. The system could be characterized by saying that it isolated the operative mental relations forming the correlations of the input and then "expressed" them by means of correlator expressions current in the output language (Ceccato, 1965).[5]

As was foreseeable, the input procedure not infrequently produced more than one relational net for a sentence and therefore a multiple output. To eliminate this and other ambiguities, Ceccato proposed what he called a "notional sphere". This was, I believe, an idea far ahead of its time. A network of common experiential or practical associations was to be elaborated and relevant parts of it were to be added to the word matrices. These notional relations could then function as a limiting control of the correlations made by the machine. An example he gave, that seemed to make the need for such an additional level very clear, was the sentence: "My jacket came back from the cleaner, but a button was missing". To grasp the inferential connection suggested by "but", one has to know that buttons can be *part of* a jacket. Similarly, without such a notional network, the meanings of sentences such as: "She had two apples for lunch" and "She had two guests for lunch", could not be properly distinguished.

The size of this network was indeed considerable, but Ceccato came to the conclusion that a mapping of some fifty notional relations would be sufficient to resolve the great majority of "semantic" problems.[6] One day, I remember, Ceccato brought to the office a little can with the label: "Chinese Mushroom Sauce Sandwich Spread Recipe", and after a day's work we realized that we had to add the relationship of a spreadable substance and solid surfaces to the "notional sphere".

These are only some of the complexities of the system, and anyone who worked with computers at the beginning of the 1960s will recall that the available "work-spaces" were small and the frequent use of external tape drives made a complex procedure so slow as to be unacceptable – even on an IBM 360, then the most powerful machine. Consequently, nothing but a few partial tests was run on a computer during the four years of the project.

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5 A brief but fair description of the system was included in Salton, 1964.

6 Bar Hillel, an authority who convinced sponsors in the US that machines could not resolve lexical ambiguities such as in the sentence: "The box is in the pen". It was a spurious example because today we know that even a small computer can be inside a pen that writes – which has brought home the fact that a human translator is no better off than a machine, when presented with such ambiguities and no further context.

The Brief Life of Adam the 2nd

In the meantime the sponsoring climate in the US had changed and the research contract of the Center for Cybernetics was not renewed in 1962. Ceccato, whose main interest had always been a theory of knowledge rather than MT, turned to the design of a machine that could "observe and describe what it perceived". Of his basic endeavor he said:

> "The antithesis which I was struggling to elaborate was precisely that of doing, of operating, as an activity, as opposed to the passivity or, rather, the false activity purported to be that of knowing in traditional philosophy" (Ceccato, 1996, p.14)

In collaboration with Enrico Maretti, the engineer of the original group, a small computer-like processor for such a machine (to be called "Adamo II"), had been designed earlier. Now, with the help of surplus optical and electronic devices which several industries such as Olivetti and Phillips contributed to this research, the perceptual component could be assembled bit by bit.

Picture: Silvio Ceccato and "Adamo II, the machine that observes and describes", in the course of its construction in March 1964.

It was completed for the 1965 Triennale, an international exhibition of industrial design in Milan. It was a period of violent student demonstration and before the opening day, a group of rabid demonstrators entered the exhibition and vandalized a number of things, among them Adamo II. There was no way of reconstructing it, because its most important components had been single donations and there was no money to replace them.

The machine had been a first attempt to implement perception and categorization according to the operational approach. However, it was able "visually" to follow outlines of objects and to recognize some of them as "a pear", "a plate", and a few more ordinary items.[7] Unfortunately it remained Ceccato's last sortie into the mechanical modeling of mental processes. For the remaining three decades of his life he devoted his energy to the solidification of his operational theory of the mind, and its application to general areas, such as education, esthetics, and various problems of individual and social living.

Correlational Grammar in Sentence Analysis

After the termination of Ceccato's MT project, I was able to survive as foreign correspondent of the Swiss weekly *Die Weltwoche* with which I had made a connection during my earlier period as a journalist. A few months later I received the request for a proposal of research in computational linguistics from AFOSR, the Washington research office of the US Air Force. The scientific direction of this office was in the hands of Harold Wooster and Rowena Swanson, two civilians of extraordinary acumen and insight in matters of scientific research. At the time, they

[7] A description of the machine's visual system was published by R. Beltrame (1965), a summary in Ceccato (1967).

were sponsoring Warren McCulloch, Heinz von Foerster, Gordon Pask, and others who had original and wholly unconventional approaches to problems of human cognition and mental processing. Wooster and Swanson had realized that MT was a very long-term goal and that it would be unattainable until some way had been found to enable computers to extract a manageable representation of meaning from texts. Their request suggested a limited project of conceptual analysis of English sentences by means of Ceccato's correlational approach. I showed their letter to Ceccato, hoping that he would agree to collaborate. After a day's thought he wished me luck and declined. The disappointment of having his own project abruptly ended, had put him off any external sponsorship.

As the Center for Cybernetics did not want to take on the new project, I looked for another institution that could function as administrator. I found it in the Institute of Engineering Information (IDAMI), whose director, Paolo Terzi, had a keen interest in automation, information retrieval, and language processing. His institute was situated in a crumbling 17th-century Palazzo in the center of Milan, and I was assigned the enormous ballroom, which until then had not been used because there was a permanent leak in the roof. When AFOSR accepted my proposal, we installed a large bucket and little infrared heating and began to work there.

In collaboration with Jehane Barton-Burns, who had worked with me during the preceding years, I had sketched out a language input procedure that would greatly diminish operating times during correlational analysis (Glasersfeld & Barton-Burns, 1962). We now developed this idea and Pier-Paolo Pisani, a wonderfully imaginative programmer, transformed it into a program that could actually run on the IBM 360. But the machine belonged to a Milan bank, and access to it, even in the small hours of the morning, was so scarce that it seriously hampered our work. After attempts with another machine, Pisani reprogrammed everything for Olivetti's experimental ELEA computer, which proved by far the most suitable for the implementation of our system, because it allowed the individual addressing of every single bit in its memory.

Development of the "Multistore System"

This was important, because the main idea of the system was to structure the machine's work space according to the correlational grammar in order to eliminate the constant returns to external tape drives during analysis. As it turned out, this was highly successful. We called the procedure "Multistore System", because it exploited computer memory in a novel way. Unlike the attempts at the Center for Cybernetics, that were programmed in COMIT, a language developed at MIT by Victor Yngve, Pisani used no higher-level programming language but wrote the entire procedure in binary masks of machine language. To organize the computer's memory, there was a deck of punched cards with almost 30,000 instructions.

Machine time was still scarce, and we therefore developed a method to test routines and subroutines that greatly surprised American visitors and may seem quite unbelievable today. Along one wall of our giant ballroom we put up half a dozen sheets of plywood, covered them with graph paper and represented on it the structure of the Multistore. By moving colored thumb tacks we were then able to simulate the computer procedure by hand. It was slow, but it had the advantage of immediately showing any bugs in the program.

After two and a half years, we were told that AFOSR was pleased with our progress, but the general financial situation had changed and they were no longer able to renew our contract in Italy. However, if we decided to move to the US, they would assist us in finding a place with access to the largest computers and continue to sponsor the project. It was a difficult decision. None of my collaborators had ever been to the US and we realized that, beyond an Air Force contract for two or three years, there was no guarantee of jobs in the future. But our enthusiasm for the work we had been doing prevailed. We packed our entire office and personal belongings on a freighter in the port of Genoa and arrived in Athens, Georgia, in November 1966. An agreement with the University of Georgia promised us access to a grand new IBM 360/65 that was about to arrive at their computer center. Jehna Barton-Burns had stayed in Italy but Brian Dutton, a linguist from Birkbeck College, London, who had occasionally collaborated with us in Milan, was hired by the University of Georgia with the understanding that he would work half-time with us.

A Second Phase in Georgia

Since everything now had to be reprogrammed, we took the opportunity to implement a greatly advanced version of the system we had been using in Milan. The Multistore now occupied an area of the machine's internal memory that could be represented by a rectangular arrangement of bytes (units of eight bits each) in 330 lines and 528 columns. The binary bit-pattern in each byte pointed to another address, and the machine's activity flowed from byte to byte, without resorting to any external lists, except at the beginning and at the end. As the word matrices were put in, the correlational indices they contained were automatically distributed as markers into the appropriate columns and the machine looked for possible matches. Where a match was found, a product matrice was created, "reclassified", and treated like a word matrix from then on. The procedure was extremely fast, given the speeds technically possible at the time.

We continued refining the system, and towards the end of 1969 I visited our sponsors in their Washington office, armed with print-outs and minute descriptions of the most recent additions. I was told that our progress had been excellent and that the continuation contract, which was to start in December, would provide for an additional full-time member of the team. Six weeks later, in mid-January, I received the notice that, owing to a reorganization of AFOSR, our contract had been cancelled.[8]

Fortunately the University of Georgia was in a phase of expansion and immediately offered jobs to us, but it was the end of the sentence analysis project. I spent the next three months writing a final report and, together with Pisani, a technical description of the system to be published in *Communications of the Association for Computing Machinery* (Glasersfeld & Pisani, 1970). It may be of interest to note that in this final version of the procedure the processing time for sentences up to 15 words was rarely more than 15 seconds. But the system did not yet

8 Ours was not the only one. I discovered. Wooster and Swanson had been sacked by the military and half a dozen large contracts of the Information Processing Division were terminated at the same time.

operate with "notional spheres" and therefore every now and then still produced more than one final relational net.

Enter the Chimpanzee Lana

In the Department of Psychology, that had adopted me as psycholinguist, I met Ray Carpenter, one of the major primatologists of the time. He had a keen interest in computers and language, and one day he asked me if I would be interested in collaborating in designing an experimental "linguistic" system for communication with chimpanzees. It was the time when the Gardners (University of Nevada) had published their first reports on the chimpanzee Washoe's exploits with sign language. The Yerkes Institute in Atlanta wanted to initiate a similar experiment with a computer-controlled language. I discussed this with my friend Pisani and we agreed to take on the design of a suitable "language" and a computer system to handle it.

The system involved a keyboard with graphic symbols for things that were thought to be of interest to a chimpanzee, a grammar according to which strings forming statements, requests, and questions could be composed, and a set of dispensers that provided what was asked for, if the requests were grammatically correct. Needless to say, the grammar was correlational, and the correctness of inputs was checked by a greatly reduced Multistore in a PDP 8 computer (see von Glasersfeld, 1974; Pisani, 1977).

The distribution of the symbols on the keys was changed every day to prevent Lana, the female chimp in the experiment, from learning spatial patterns instead of sequences of symbols. She was able to manage this very well and on video tapes one could see her scanning the keyboard for particular keys. At the end of the project Lana's keyboard had grown to hold a hundred keys. Input strings were limited to seven "words", and the character of the string had to be indicated by the first symbol: "Please" for requests, "?" for questions, and no indicator for statements. The end had to be marked by a period sign. To prevent Lana from pressing two keys at the same time, a bar that switched on the computer was placed above the keyboard, and she had to hang on to it with one hand while she was pressing keys.

The system was operative 24 hours a day, and after about eighteen months, Lana fed herself via computer by typing "Please machine give piece of banana", "...of apple", "... of monkey chow", "milk", "water", etc. The only food she received by hand was some fresh vegetables that could not be handled by the mechanical dispensers. Everything she typed into the machine was recorded.

An examination of the input showed some interesting things. In the middle of the night, for instance, she occasionally made ten or more consecutive requests for the little chocolates called "M&M" that were also automatically dispensed to her. Immediately afterwards she requested "Please machine make movie", which activated a projector to run a strip of film showing primates in the wild. The examination also showed that, apart from requests that were the result of training, the vast majority of statements she typed in were grammatical,[9] a statistical fact that has been consistently ignored by the critics of the chimpanzee experiments ever since. Lana produced a

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9 The Yerkish grammar and statistics of Lana's errors and correct sentences during one month are given in Glasersfeld, 1977.

variety of spontaneous sentences that were not only grammatically correct but also made perfect sense in the contexts in which she typed them into the machine. They were, of course, single instances and, from the prevailing behaviorist point of view, purely "anecdotal" and of no scientific value.

Concluding Remarks

With the termination of the "Language Project" at the Yerkes Institute in 1976, the only computer application of correlational grammar came to an end.[10] Its reduced version had worked flawlessly on a PDP 8; in its full implementation as sentence analysis procedure on the 360/65 at the University of Georgia in 1969, it had consistently produced coherent nets of conceptual relations expressed by English sentences. These nets could have served as a sophisticated basis for output in other languages, provided the correlational analysis for the output language had been carried out. This would have taken another two or three years of intensive work for each single language. As this was not undertaken, there is no hard evidence to confirm that the system would have yielded a superior translation procedure.

A most important application of Ceccato's seminal ideas outside the domain of computational linguistics is the minute operational analysis of lexical items carried out during the past forty-five years by Giuseppe Vaccarino, the logician of Ceccato's original group. He became professor of philosophy at the University of Messina and devoted his life to the conceptual analysis of the entire Italian vocabulary. Among several other books, he published intermediate results (Vaccarino, 1977; 1988; 1997) and is now, at the age of eighty, in the process of completing a dictionary.

As to Ceccato's operational theory, it has had some influence on the development of the "Methodical Constructivism" of the Erlangen School (Janich, 1996) and on operationist philosophies in Italy and the German-speaking area. But his contribution to computational linguistics, as far as I know, has never been taken up by anyone. As the operative memory in today's computers is practically unlimited, a system such as the Multistore, that compresses procedures to a minimum at the cost of an enormous programming effort, is probably of little interest now. Nevertheless some of the semantic subtleties that were isolated and worked out during the research with correlational grammar might still be useful to the MT procedures that are currently being employed.

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[10] Communication experiments with chimpanzees continued at the Yerkes Center and the Yerkish symbols were still used, but the Multistore system of grammatical analysis was scrapped and the "correctness" of messages was established by the observation of the receiver's responses.

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