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chapter 5

The Yerkish Language and Its Automatic Parser

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PRELIMINARY REMARKS

It might seem reasonable to divide the description of the language Lana is using into three sections so that each would reflect one of the three criteria for the recognition of language set out in Chapter 2 of this book; but only two of the criteria will serve that purpose. The division implied by the first and the third criteria (a set or a *lexicon* of artificial signs and a *grammar* that governs the combinatorial patterning of signs) is a division traditionally made by linguists in their description of languages, and I shall adhere to it, even though my classification of the lexicon and the "correlational" grammar I am using do not conform to traditional linguistics. The second criterion, however, concerns the *symbolic use* of signs and not the signs themselves (von Glasersfeld, 1974b). As I explained in Chapter 2, any artificial sign can be used symbolically, since this use in no way depends on the physical characteristics of the sign or on its meaning.[1] The

[1] There is not a single word in our natural languages that could not be used symbolically. Even demonstrative adjectives and other expressions that would seem to be irrevocably tied to perceptually present items by their "pointing" function are severed from the perceptually present (and thus become symbols) when they are used in hypothetical or fictional contexts.

description of a language, therefore, need not and indeed cannot include anything concerning "symbolicity" (that is, character and function of symbols).

Yerkish is an artificial language that was designed for the specific purpose of exploring the linguistic potential of nonhuman primates. It was designed under a number of constraints, both theoretical and practical. In what follows I shall try to show which aspects of the language were determined by these initial practical constraints and which by the theory underlying its design. Since the language was created at the same time as the computer system that monitors all the communication events for which it is used, there will inevitably be some overlap in the description of the language and that of the automatic sentence analyzer, or parser. Also, since the grammar we are using is a correlational grammar, i.e., one that takes into account the *semantic* aspects of combinatorial patterns (unlike traditional systems of grammar, which tend to consider *syntactic structures* quite apart from semantics), the description of the lexicon and that of the grammar will have to merge at several points. Nevertheless, this chapter will be articulated into relatively independent sections dealing with the word signs (lexigrams), the meaning and grammatical classification of word signs, combinatorial patterns, the parsing system, and, finally, a brief application of the concept of grammaticality to a sample of Lana's output.

DESIGN OF THE LEXIGRAMS

At the very inception of the project it had been decided that, in view of the success the Gardners had with American Sign Language (Gardner & Gardner, 1969, 1971, Fouts, 1974) and Premack had with word signs made of plastic shapes (Premack, 1971), the language would be visual. Moreover, the visual word signs were to be fixed units, so that each one could be placed on a separate key of a keyboard, which would serve as an input device to a computer. After these decisions had been made, but before the actual work on the project had begun, I spent my spare time trying to devise a feasible graphic system in which word signs could be composed out of design elements in such a way that each design element would have a constant semantic value. Apart from its theoretical attractiveness, the idea was tempting because a language in which all word signs were made up of meaningful design elements (corresponding to *morphemes* in natural languages) would open up innumerable possibilities for testing our subject's conceptual development. Since the vocabulary of the subjects was not

Table 1
SEMANTIC COLOR-CODING OF LEXIGRAMS

Color	General type	Lexigram classes
Violet	Autonomous actor	AP, AV, AO, AM.
Orange	Spatial objects, Spatial concepts	FA, FP, TF, CT, WR.
Red	Ingestibles	EU, EM, ED.
Green	Parts of body	PB.
Blue-gray	States and conditions	ST, LS, CD.
Blue	Activities	VA, VB, VC, VD, VE, VG, VL, VM, VP, VS, VT, VW.
Black	Prepositions, determiners, particles	DC, DD, DQ, DP, LP, IF, NF, PP, XA.
White[a]	Affirmation	"YES."
Yellow[a]	Sentential modifiers	Query, Please, Negation, Period.

[a] White and yellow are available for sentential modifiers only. They must be placed at the beginning of a message.

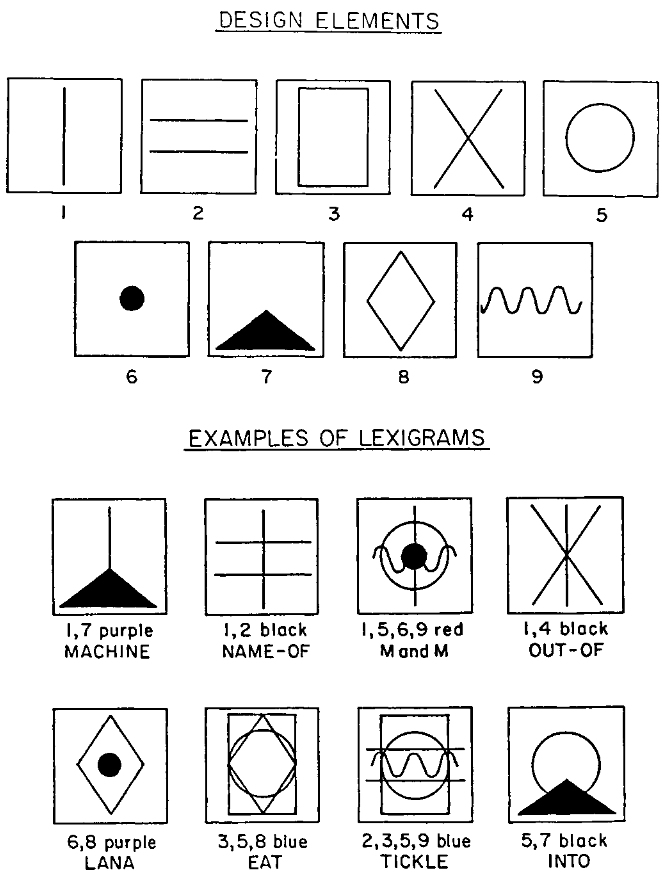
expected ever to exceed a few hundred items, the design of such a graphic system seemed quite possible.[2]

Once work on the mechanical and electronic machinery that was to constitute the interface with the computer had begun, it became clear that, for reasons of technical construction and budget, the design elements would have to be limited to 12 (see Chapter 7 of this volume). This limitation posed a new problem since with a dozen elements there is no possibility of semantic constancy even in a universe of discourse as limited as the one that was foreseen for a chimpanzee. To avoid having design elements that were sometimes semantically indicative and sometimes not, I gave them no semantic significance at all. Thus they became theoretically equivalent to phonemes in spoken language (or "cenemes" in Hockett's terminology; cf. Hockett, 1961, p. 47). There was, however, a big difference. While the user of a natural human language composes his utterances from the fixed set of preestablished vocal elements that linguists call "phonemes," the user of our artificial language (at least for the time being) would not be concerned with the composition of word signs out of design elements because the word signs would appear as fixed lexigrams on the keys of the keyboard.

The first task, then, was to choose design elements that were readily discriminable from each other, could be superimposed on one another, and

[2] The American Indian language, Yuchi, for instance, has phonemes that are constant semantic markers in the formation of nouns; and the Arabic language, especially in its classical form, conveys a great deal of abstract categorial information by the insertion of semantically constant vowels into consonant verb roots.

Table 2



once superimposed would yield combinations that were still discriminable. Since the total number of lexigrams was to remain within the range of a few hundred, it was clear that we would be able to manage with something less than a dozen design elements. Nine elements used singly and in combinations of two, three, and four would yield 255 individually different lexigrams, and that was considered more than sufficient. In addition to the nine design elements, we decided to use three colors, selecting them so that superimposing one on another gave rise to three intermediary colors.[3] Since

[3] Since the limitation on design elements was imposed by the structure of the "feedback projectors" (see Chapter 7 of this volume) the mixing of the three basic colors takes place in

the colors would modify the background and not the graphic designs, which would always appear in white, the absence of a color element would produce a black background. For the combinatorial design of lexigrams, therefore, we had nine graphic elements and a total of seven background colors. To characterize a few additional items that are not subject to the same rules as ordinary lexigrams (because they function as "sentence markers"; see page 102), two special elements were used: a blank white field and a yellow background.

Having thus regained a certain amount of flexibility, I decided to use the seven background colors for a gross semantic classification and assigned each color to serve as the background for one class of items only. Such a limited classification would necessarily be crude, but would still permit some tests of our subject's conceptual categorization. (For the color code, see Table 1.)

As design elements, seven line-figures were chosen that satisfied a theoretical criterion of discriminability: If placed on a 30 × 45-point grid, none of them shared more than 50% of its grid points with another figure. Two filled-in figures, a small circle and a flat isosceles triangle, completed the set of nine graphic elements (see Table 2).

THE LEXICON

One of the first considerations in the choice of lexical items concerned the interactive character of the communication facility. Because the computer that monitors all linguistic transactions is programmed to respond to certain correctly formulated requests by activating the mechanical devices that fulfill the requests, the lexicon had to contain all the items that could possibly be put under automatic management. Besides food and drink, the possibilities included the playing of taped music or sounds, the projection of movies and slides, the opening and shutting of a window, and, though these have not yet been implemented, the switching on and off of lights and raising and lowering the room temperature. Altogether these possible requests involved some 30 lexical items.

In providing for requests addressed not to the computer but to a human agent (i.e., one of the technicians), we attempted to create lexigrams for as many activities, objects, states, and relational concepts that might conceivably play a part in linguistic exchanges with a captive chimpanzee.

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projection. The graphic elements appear in white and their background is either colored or black, according to what color elements are combined with them. The addition of 7 colors to the design elements raised the total of possible combinations of 2, 3, and 4 elements to 1785.

After I had gathered all the information I could from the primatologists and behavior specialists of the team, I devised a preliminary vocabulary of some 150 words supposed to reflect items and activities that might be of interest both to experimenters and chimpanzee in the kind of environment the Yerkes Center was providing for our communication study. The result was inevitably an anthropocentric vocabulary. There is some evidence, it is true, that the great apes organize their perceptual world in a manner compatible with our own, but we know little about what—if anything—might motivate a lone captive chimpanzee to communicate with a machine or a human technician. Since our subject was and still is years away from sexual maturity, food and drink were the only safe bets. Thus it was gratifying to observe that Lana showed a very constant interest in two additional incentives we devised, the projection of a movie and of slides, and that she also came to use a window-opening phrase whenever some noise from the outside led her to suspect that there might be something worth seeing out there.

Another consideration in the compilation of the lexicon was the need to avoid ambiguity. If a language is to be used as a means of communication and not as the raw material for the composition of poetry or emotionally suggestive prose, words that have more than one meaning should be avoided because they inevitably complicate the process of interpretation. Although it can be said that all natural languages contain words with more than one meaning, this feature is in no way a requirement for their communicatory function. Insofar as possible, therefore, lexigrams were chosen to designate only one type of item. Thereby we eliminated a gratuitous difficulty for the subject and also made it possible to design the automatic parser in a much more compact way because it did not need complex disambiguation procedures.

The Yerkish lexigrams, thus, have one meaning each, and this one meaning in most cases corresponds to one meaning of an English word. Since most items in the English lexicon have more than one meaning, there is no one-to-one relation between English words and lexigrams. For instance, the English words "back," "ear," "eye," "foot," and "head," can all, depending on the context, designate objects, activities, or attributes. Although the different usages of a word may all derive from a single, underlying concept (e.g., "my back," "to back my car," and "the back seat") some of these words can, in addition, designate several items which conceptually have little or nothing to do with one another (e.g., an ear of a rabbit and an ear of corn). The Yerkish lexigrams that correspond to the English words listed above, however, designate parts of the body exclusively. In a few exceptional cases, the meaning of a lexigram is somewhat larger than that of a single English word and has to be translated by means of a word combination (e.g., *name-of, which-is, out-of*).

In a traditional lexicon, it is customary to divide the lexical items (words) into nouns, verbs, adjectives, etc. This grammatical classification derives from the roles (parts of speech) words play in sentences. In a language such as Latin, this type of classification is a rather obvious descriptive device, since Latin words in most cases change their form according to the role they play, and are morphologically marked for specific parts of speech (e.g., *amor*, noun; *amare*, infinitive verb; *amo*, finite first person present indicative.)In English the morphological marking of parts of speech has all but disappeared, and hence there is no obvious reason why the word *love*, for example, when taken by itself and *not* as part of a specific string of words, should be considered a noun rather than an infinitive or a finite verb form. What is more important is the fact that this grammatical classification, both in Latin and in English, is based predominantly on the linguistic characteristics of lexical items and their use and not on the conceptual characteristics of the items they designate. A linguist faced with the two sentences *I love Mary a lot* and *I have a lot of love for Mary* must classify *love* as verb in the first and as noun in the second. Because verbs are supposed to designate activities or processes, and nouns things or static items, this classification inevitably produces the misleading impression that *love* expresses an activity in the one sentence but not in the other. Yet on the conceptual level *love* in both sentences designates neither an activity nor a thing but a relationship. Traditional grammars relegate such considerations of meaning, or underlying concepts, to the realm of semantics and continue to formulate their rules in terms of the old grammatical word-classes. This is one point where correlational grammar departs from the tradition (Ceccato, 1949; Ceccato, Beltrame, von Glasersfeld, Perschke, Maretti, Zonta, & Albani, 1960, 1963; von Glasersfeld, 1961, 1969). The lexicon with which a correlational grammar operates is divided into classes that are defined not in terms of the morphological characteristics of words, but in terms of the functional characteristics of concepts. These functional characteristics are derived from the role or roles the concept plays in the cognitive representation of experiential situations. In the case of "things," for instance, these characteristics include the kinds of activity the thing can perform as actor and the kinds of activity in which it can play the part of direct object; in the case of "activities" the characteristics include the kinds of change the activity can bring about, the kinds of material it requires, etc.

Though the Yerkish universe of discourse—the set of things about which one can communicate in Yerkish—is at present only a small fraction of that of English or any other natural language, it could be considerably expanded without increasing or altering the grammar currently in use. As it is, the system allows for 46 lexigram-classes of which 37 are in use at the moment. Thus nine more classes can be added, and this addition would expand the system by 25%. A much larger expansion, however, could be achieved by simply increasing the number of lexigrams in those classes that do not contain special function words. In the present arrangement, 25 of the 37 operative classes fall into that category. By filling them with new items, we could at once reach the system's ceiling of 250 lexigrams and greatly increase the possibilities of expression. This has not been done because it seemed far more interesting to explore our subject's capabilities with regard to sentence structure rather than her retention of ever larger numbers of lexical items.

THE CONCEPTUAL LEXIGRAM CLASSES

In the following section, I shall briefly describe the lexigram classes that are in operation at present and list the items in each class that have been used by Lana already or are now ready for insertion into the system. Items from this latter category will appear in parentheses.

Items that can eat, drink, groom, tickle, bite, and/or give things or make things happen in the environment, are called "Autonomous Actors." They are subdivided into four groups and thus gave rise to four lexigram classes:

Familiar Primates (AP), i.e., human and nonhuman primates that can be addressed by name: *Beverly, Billy, Lana, Tim.*

The personal pronouns *you* and *me*, since they are reciprocally applied to the same kind of item, have been added to this class. In Yerkish, however, personal pronouns do not mark a case. Hence, the sentences *You tickle me* and *Me tickle you* are both grammatically correct.

Unfamiliar Primates (AV), i.e., human and nonhuman primates that cannot be addressed by name because no name has been assigned to them. At present the lexigram *visitor* is the only member of this class.

At some future date we may introduce lexigrams for *man, woman*, and *ape*. When that is done, we shall have to decide whether or not a sentence such as *Please man move into room* should be accepted in Yerkish. I believe it would be more interesting to allow only *you* and proper names as vocatives.

Nonprimates (AO), i.e., other animate organisms. At present this class contains only the lexigram for *roach*.

Since our subjects are expected to get access to an outdoor compound, more animal names will eventually be inserted into this class.

Inanimate Actor (AM), i.e., the "machine," which comprises the computer, the keyboards, and all the computer-activated mechanisms. The single lexigram in this class is *machine*.

The differences between these four classes spring from the fact that some of the items can perform activities that the others cannot. The primates and the machine, for example, can respond to requests for "giving" things and for "making" certain changes in the environment; a nonprimate such as a roach cannot respond to that kind of request. Similarly, primates and nonprimates can eat and drink, whereas the machine cannot.

Those objects which we often refer to as "physical objects," i.e., items that are tangible and have a location in space, are divided into several classes according to their mobility and/or their function.

Absolute Fixtures (FA), i.e., items that can neither move nor be moved: *cage, piano, room, (keyboard).*

(Note: the "piano" is a small second keyboard used to test the subject's musical abilities.)

Relative Fixtures (FP), i.e., items that cannot change their location but can change their configuration by "stationary" motion: *door, window.*

Although the window can be opened automatically by a suitable request addressed to the machine, the door can be opened only by a request addressed to a technician.

Transferables (TF), i.e., items that can change place and hands, that can be "given" by one actor to another: *ball, blanket, bowl, box, can, cup, feces, shoe.*

Some of these items are sometimes placed into a computer-activated hopper, and then they can be obtained by a request addressed to the machine. Otherwise requests for them have to be addressed to a technician.

Parts of Body (PB), these are items that can change their location but cannot change hands: *ear, eye, foot, hand, mouth, nose.*

Solid and liquid food items are divided into three classes because the solids are divided into "units" and "materials." This second division was made for two reasons. The automatic dispensers were too small to handle whole bananas and apples, and it also makes for a better training situation if the subject receives small pieces and thus has to formulate the request all the more frequently. This arrangement makes it possible to differentiate requests for a whole item from requests for a piece of an item by means of two different sentence structures.

Edible Units (EU), i.e., food items that are dispensed as wholes: *M&M, (nut, raisin).*

Edible Materials (EM), i.e., food items that are dispensed in pieces: *apple, banana, bread, cabbage, chow.*

Drinks (ED), i.e., ingestible liquids: *coffee, coke, juice, milk, water.*

A special class of conceptual categories is represented by lexigrams which serve to indicate conceptual parts of spatially extended items. They have one grammatical feature in common: They are used with the preposition "of."

Conceptual Categories (CT), applicable to spatial items: *color, piece, (beginning, bottom, end, side, top).*

One more class that would fall into the traditional category of nouns is formed by lexigrams that designate perceptual items of a special kind: states of the environment that are caused by an agent.

Ambiental Conditions (CD), i.e., percepts considered the result of an agent's activity: *movie, music, slide, TV, (cold, heat, light).*

In the category traditionally called adjectives, there are at present a set of color terms and two lexigrams designating "open" and "shut."

States (ST), i.e., properties that can be predicated of other items: *black, blue, green, open, orange, purple, red, shut, white, yellow, (clean, cold, dirty, hard, hot, soft).*

Spatial indications are divided into three classes. The first of these contains spatial adverbs that can be used in predicative constructions. The other two correspond to prepositions.

Locational States (LS), i.e., spatial indications that can be predicated of other items: *away, down, here, up.*

Locational Prepositions (LP), i.e., items that function as markers for relational concepts and specify the spatial location of the item that precedes them (i.e., where it is) relative to the location of the item that follows: *in, on, outside, under.*

Directional Prepositions (DP), i.e., items that function as markers for relational concepts and specify the direction of the item that precedes them (i.e., where it is going) relative to the location of the item that follows: *behind, into, out-of, to.*

As Yerkish has at present no tenses or other indications of time, it also contains no prepositions for temporal relations. Once lexigrams designating temporal or sequential concepts are introduced, it will be interesting to see if our subjects extend the use of *in* and *on* to the temporal domain. It should not surprise us if they do, since on the conceptual level inclusion and other spatial relations arise from an attentional pattern that is neither spatial nor temporal in itself.

Several other lexigrams also designate relational concepts. One of them is translated as *of* and corresponds to the partitive function of the English preposition; that is, it expresses the part–whole relation. It does not, however, express the possessive relationship or any of the other possible meanings of the English word "of." Thus, in Yerkish one can say *color of banana, piece of apple*, or *top of box*, but not *friend of Tim, sign of fear*, or *house of cards*.

Partitive Preposition (PP), i.e., indication of part–whole relation: *of.*

Recently a lexigram for "and" was created, but it corresponds to a small part of the range of uses of the English conjunction. It can be used to link two actors or two direct objects of one and the same activity but not to link two phrases or sentences.

Additive Conjunction (XA), i.e., indication of dual agent or dual object: *and.*

Three lexigrams designate relations for which there is no one-word expression in English. One of them indicates the semantic connection between a lexigram and the item it designates; the other two, the relations of sameness and difference.

Semantic Indicator (NF), i.e., indication of semantic nexus: *name-of.*

Similarity–Difference Marker (IF): *same-as, different-from.*

The last of the "two-word" lexigrams designates the relations of attribution or specification that connect an item and a property, either when that property is attributed to it (in English by an attributive adjective) or when the item is characterized by means of the property (in English by a relative clause; see page 116).

Attributive Marker (WR): *which-is.*

At the time of writing, nine classes of activity lexigrams as listed below have been used, and three more (listed in parentheses) are ready for insertion. Some of the activities necessarily involve a direct object (transitive = t.); some of them cannot involve a direct object (intransitive = i.), and some of them may function either way (i. & t.).

Ingestion of Solids (VE) i. & t.: *eat.*

Ingestion of Liquids (VD) i. & t.: *drink.*

Relational Motor Act (VA) i. & t.: *groom, tickle.*

Transferring (VB) t. (locomotion causing object's change of place): *carry.*

Locomotion (VL) i. (change of place): *move, swing.*

Change of Place and State (VT) t.: *put.*

Change of Hands (VG) t.: *give.*

Conative Activity (VW) t.: *want.*

Causing or Creating Change (VM) t.: *make.*

Application of Force (VC) t.: (*pull, push.*)

Maintaining Position (VS) i.: (*lie, sleep, stand.*)

Perceptual Activities (VP) t.: (*feel, hear, see.*)

Finally Yerkish contains three classes of particles, which correspond to "determiners." As in English, they are used in the place of articles, but since Yerkish has no articles, some of these lexigrams have a wider range than their English translations.

Demonstrative (DD): *this, what.*

Quantitative (DQ): (*all, many*), *no*, (*one*).

Comparative (DC): *less, more.*

There are five other graphic signs that differ from ordinary lexigrams in that their position in a string (i.e., a sequence of lexigrams) is fixed. Four of them can be used only as the first item at the beginning of a phrase or sentence, and they modify the mood of the whole utterance that follows; i.e., they are "sentential markers." The fifth is the equivalent of a "period" and is placed at the end of every utterance.

Request Sign (imperative): *please*

Query (interrogative): "?"

Negation: *not*

Affirmation: *yes*

End-of-message Sign: "."

AN INTERPRETIVE CORRELATIONAL GRAMMAR[4]

The grammar of Yerkish was derived from the "correlational" grammar implemented some years ago in the *Multistore parser* for English sentences (von Glasersfeld, 1964, 1965, 1970; von Glasersfeld & Pisani, 1968, 1970). It is an *interpretive* grammar and lays no claim to being "generative" or "transformational" in the Chomskian sense of these terms.

Although the theoretical bases of the correlational approach to grammar were published 15 years ago (Ceccato *et al.*, 1960), the revolutionary idea contained in this approach has been slow to spread. Put very simply, the idea is the realization that no language can be satisfactorily analyzed and described unless one has a viable analysis and classification of the nonlinguistic conceptual structures that find expression in language. Ideally, a correlational grammar should contain a complete mapping of the semantic connections between the elements and structures of a given language, on the one hand, and the elements and structures of conceptual representation, on the other. The amount of work required to produce such a mapping for any natural language is, of course, vast. Fillmore's (1968) "case grammar" sprang from a similar relational approach. The work of Charniak (1972) and the painstaking analyses of conceptual dependency by Schank (1972, 1973, 1975) represent substantial advances in this line of research. It will take a good deal more time and effort to map the conceptual semantics of the average language user's universe of discourse, but it should not really surprise anyone that language turns out to be an enormously complex system. What matters is that enough progress has been made to encourage the hope that the task can, indeed, be completed.

In this context it must be said that Chomsky's introduction of the terms "surface structure" and "deep structure" (Chomsky, 1956, 1965) seemed a step in the right direction, but his interpretation of deep structures has remained wholly dependent on linguistic concepts. This limitation prevented him and his followers from getting down to the truly characteristic features of the underlying structures, namely, the cognitive operations and routines by means of which these structures are put together. Thus, since Chomsky does not attempt to specify deep structures in their own cognitive terms, he can specify them only insofar as they differ in their surface expression (i.e., on the linguistic level); he cavalierly leaves all the really interesting cognitive part to the intuition of the native speaker and to

[4] Parts of this description of the grammar of Yerkish have appeared in the *American Journal of Computational Linguistics* (Vol. 1, 1974, microfiche 12) and are reprinted here by courtesy of the publisher.

mysterious innate processes. Indeed, as Chomsky (1956) was careful to state and as he reiterated (1965), his generative–transformational grammar was intended as a linguist's description of language and *not* as a model of the language-user.

Correlational grammar, on the other hand, is an interpretive device and aims at providing a model of the language-user in the receiving role. (Note that "model" in this context means a mechanism that, given the same input as the thing to be modeled, will yield the same output, although it may employ quite different means to do so.) Correlational grammar, therefore, is not primarily concerned with demonstrating in an axiomatic way that every grammatically correct phrase or sentence is a case under a formalized rule or set of rules, but rather with transforming the *content* of a given piece of language into a canonical form of preestablished conceptual–semantic elements or modules. An interpretive system of this kind presupposes the grammaticality of its input. But since it is designed to interpret all grammatical pieces of language, it can be used to define operationally as "grammatical" any input that it can interpret, and as "ungrammatical" any input that it *cannot*.

When designing a correlational grammar for a *natural* language, the task of bringing the interpretive capability of the grammar to a level anywhere near the interpretive capability of the native user of the language is truly enormous. In the case of an artificial language, however, this problem is altogether eliminated because the lexicon, the rules of concatenation, and the interpretive grammar can all be designed at the same time. Since there is no native user who already has a universe of experiential content and well-established semantic connections (by means of which this content is linked to linguistic expressions), the designer is free to tailor the lexicon as well as the syntax of his language to the universe of discourse he envisages.

That is to a large extent how Yerkish was designed, especially with regard to the rules of grammar. The result is that the user of Yerkish can communicate in grammatically correct lexigram strings no more than the correlational grammar of Yerkish can interpret.

In creating an artificial language, the semantic connections between the signs (words, gestural signs, or lexigrams) and their meanings can be made as univocal (unambiguous) as desired. Moreover, because Yerkish is based on English and because the output of subjects in the experimental environment is evaluated by speakers of English, the lexical semantics of Yerkish (i.e., the meaning of single lexigrams) could be left implicit to a certain extent. For example, the Yerkish parser does not have to contain an exhaustive semantic analysis of lexigrams such as *ball* or *banana* because it can be taken for granted that the reader of the parser's output will be quite familiar with the concepts designated by these two words. What the parser must contain, however, is a mapping of those specific characteristics of concepts that determine their potential for entering into structural relations with other items.

In any correlational grammar, the relational characteristics of conceptual items determine the classification of lexical items. Thus, if the language is to contain items that can be eaten and items that can be drunk, the lexigrams designating these items will be divided into *edibles* (classes EM and EU, i.e., direct objects suitable for the activity designated by *eat*) and *drinkables* (class ED, i.e., direct objects suitable for the activity designated by *drink*).

In short, Yerkish grammar requires a lexicon in which classes of lexical items are exhaustively characterized with regard to the specific relations into which their members can enter with members of other classes. This exhaustive characterization of each lexigram is supplied not by listing all the other classes with whose members it can potentially form connections but by a string of indices each of which specifies a connective relation and the place in it a member of that class can occupy. Thus we come to the relational concepts, or *correlators*, which are instrumental in the building up of complex structures both on the conceptual and on the linguistic level. Strictly speaking, a correlator is a connective function that links conceptual items on the cognitive, representational level. Natural languages indicate these connective functions by a variety of means: prepositions, verbs, nouns, and other types of words that incorporate a preposition (e.g., *enter, entry, invade*, and *income*, incorporate the relation designated by the preposition *in*), conjunctions and other particles, syntactic markers, and frequently word-order. Since these linguistic elements indicate correlators, we should call them "correlator expressions." However, once it has been made clear that correlators function on the conceptual level, connecting concepts with other concepts or combinations of concepts, we can in most cases use the term "correlator" for both the relational concepts and the linguistic devices that express them.[5]

In designing an artificial language, the classification of lexical items and the definition or explication of relational concepts must go hand in hand since the first is done in terms of the second. The relational concepts have to be explicitly listed and explicated by some sort of paraphrase. In principle, that is what a "case grammar" does. Its cases, basically, are relational concepts (see, for example, Fillmore, 1968). Correlational grammar, however, attempts to cover not only the generic relational concepts underlying

[5] One area where the distinction has to be maintained is the semantic analysis of natural languages, because correlator expressions such as prepositions rarely have a one-to-one correspondence to relational concepts. Instead, they mark the presence of one of a set of relational concepts.

the "syntactic" functions of traditional grammar but also as much as possible of those relational concepts that traditionally have been considered "semantic." Its list of correlators, therefore, is very much longer and more specific than the lists of "cases" that have been suggested by the proponents of case grammars.

CORRELATORS: THE CONNECTIVE FUNCTIONS OF YERKISH

In its present form,[6] the Yerkish grammar operates with some 30 correlators. The first 10 of these correspond to what, in traditional grammars, is subsumed under the generic subject–verb relation. Here they are subdivided according to the type of actor and the type of activity. There are five actor/activity correlators that require an "autonomous animate actor" (AP, AV, or AO):

01 autonomous animate actor / performing / stationary activity (VA, VE, VD)

```
Lana                     drink
 └--------------- 01 ------┘
```

02 autonomous animate actor / performing / transferring activity (VB, VT)

```
Tim                    carry               Lana
 |                       └------- 14 --------┘
 └--------------- 02 ------┘
```

03 autonomous animate actor / performing / activity requiring contact and force (VC)

```
Lana                     push
 └--------------- 03 ------┘
```

04 autonomous animate actor / performing / perceptual activity (VP)

```
Lana                   see                 box
 |                       └------- 16 --------┘
 └--------------- 04 ------┘
```

09 autonomous animate actor / performing / conative activity (VW)

```
Lana                   want                apple
 |                       └------- 19 --------┘
 └--------------- 09 ------┘
```

[6] Note that in this and the three following sections I am describing the Yerkish grammar and not Lana's performance. The examples given here were chosen to demonstrate the grammar, and many of them *have never been used by Lana*.

Two actor/activity correlators require an "intentional causative agent–actor," i.e., a primate or the machine (AP, AV, AM):

05 causative agent / causing / item's change of hands (VG)

```
Machine              give               M&M
   |                   L---------- 17 ----------J
   L-------------- 05 -----------------------J
```

06 causative agent / causing / item's or ambiental change of state (VM)

```
Machine              make               movie
   |                   L---------- 18 ----------J
   L-------------- 06 -----------------------J
```

Two further actor/activity correlators can have as actor any item that is capable of changing its spatial location:

07 movable actor / performing / locomotion, i.e., changing its own place (VL)

```
Tim                                  move
 L----------------- 07 ------------------J
```

08 movable actor / performing / stative activity without change of place (VS)

```
Shelley                              stand
   L--------------- 08 ------------------J
```

The last correlator that corresponds to the traditional subject–verb class but does *not* involve an activity is that of the simple predicative relation. In English this relation is expressed by the so-called auxiliary verb *to be*. Yerkish, however, contains no auxiliaries, and the predicative relation is designated by the mere juxtaposition of an item and the property (ST) or locational state (LS) that is predicated of it:

10 item / described by / predicated state

```
banana                               black
   L--------------- 10 ------------------J
```

Next there is a group of ten correlators which correspond to what in traditional grammars is subsumed under the generic "verb-object" relation. In Yerkish they are again subdivided according to the type of activity and the type of item that serves as patient:

11 ingestion of liquids / involving as patient / solid food (EU or *piece-of* EM)

```
eat                                  M&M
 L----------------- 11 ------------------J
```

12 ingestion of liquids / involving as patient / liquid (ED)

```
drink                           juice
  └------------- 12 -------------┘
```

13 relational motor act / involving as patient / any spatial item

```
groom                           Lana
  └------------- 13 -------------┘
```

14 transferring / involving as patient / item capable of change of place

```
carry                           Lana
  └------------- 14 -------------┘
```

15 act + contact and force / involving as patient / any spatial item

```
push                            box
  └------------- 15 -------------┘
```

16 perceptual activity / involving as patient / perceptual item

```
hear                            music
  └------------- 16 -------------┘
```

17 change of hands / involving as patient / handable item

```
give                            M&M
  └------------- 17 -------------┘
```

18 causing change / involving as patient / resulting state

```
make                            movie
  └------------- 18 -------------┘
```

19 conative activity / involving as patient / desired item, state, or activity

```
want                            apple
  └------------- 19 -------------┘
```

20 change of place and state / involving as patient / item capable of changing place

```
put                             cup
 └-------------- 20 -------------┘
```

Several correlators concern spatial relations. There are two basic types, one involving a *directional* indication, the other a *locational* one. In each case, the specific direction or location can be indicated by one of the locative lexigrams (LS) or by a prepositional phrase. By "prepositional phrase" we mean an already made combination consisting of a preposition and some other item that specifies the location. For technical reasons these prepositional phrases are correlated separately in the present system and form a preliminary step toward the correlation of the spatial relation proper.

Hence the constructions involving a preposition (DP or LP) as indicator of a spatial relation requires two correlators to be applied in succession:

22 directional preposition / step 1 for Correlator 21 / specification of target

```
out-of                               room
  L-------------- 22------------------J
```

21 change of place / involving as target / product of Correlator 22

```
move               out-of            room
 |                   L-------- 22---------J
 L--------------- 21------------------J
```

24 locational preposition / step 1 for Correlator 23 / specification of location

```
in                                   room
L----------------- 24-------------------J
```

23 stative activity / involving as location / product of Correlator 24

```
sleep               in                room
 |                   L---------- 24----------J
 L--------------- 23------------------J
```

The second step of this construction can also be formed with the activity lexigram *put*. It then expresses the complex relations "change of place" and subsequent "state in place" of the direct object. (For example, *to put a ball on the table* means to move the ball from where it is onto the table and to make it stay there.)

29 change of place and state / involving as target / product of correlator 22 or 24

```
put              ball   into              box
 L-------- 20---------J   L-------- 22---------J
           L------------ 29--------------J
```

Two further correlators that function in the same way as those of the spatial relations are expressed by the "partitive" preposition *of* and the "additive" conjunction *and*. For both there is again a two-step construction:

25 item considered "part" / step 1 for Correlator 26 / partitive preposition

```
piece                                of
  L---------------- 25------------------J
```

26 product of Correlator 25 / part–whole relation / item considered "whole"

```
piece              of                banana
  L---------- 25-------------J            |
            L------------------ 26----------------J
```

34 additive conjunction (XA) / step 1 for Correlator 35 / second item of couple

```
and                                water
 └---------------- 34 ----------------┘
```

35 first item of couple / conjunctive relation / product of Correlator 34

```
juice                 and                  water
 │                     └------- 34 -------┘
 └---------------- 35 ----------┘
```

The relation between an item and the lexigram that has been chosen as its name is expressed by the lexigram *name-of*, which is also constructed in two steps, the first of which usually involves the demonstrative *this* accompanied by some form of ostensive indication of the item to be named.

27 semantic indicator (NF) / step 1 for Correlator 28 / item to be named

```
name-of                             this
    └------------- 27 ----------------┘
```

28 new lexigram or *what* / semantic nexus / product of Correlator 27

```
what                 name-of               this
 │                       └------ 27 --------┘
 └---------------- 28 ----------┘
```

Of the many varied relations of specification which in natural languages are expressed by articles, quantifiers, demonstratives, interrogatory adjectives etc., Yerkish contains only two at present. There is one correlator for the relations indicated by demonstrative, quantifying, and interrogative lexigrams (DD and DQ) and another for the relation indicated by the comparative lexigrams *more* and *less* and the item to which they are applied.

30 determiner / applied to / item to be specified

```
this                               apple
 └---------------- 30 ----------------┘
```

32 comparative quantifier / applied to / item to be specified

```
more                               juice
   └-------------- 32 ----------------┘
```

Another correlator functions as specification in the sense of a restrictive relative clause in natural language. It is expressed by the compound lexigram *which-is* (WR) first correlated to the specification by means of the predicative Correlator 10 and then by Correlator 31 to the item to be specified.

31 item to be specified / attribution / restriction marker (WH)

```
apple              which-is            red
  |                  L-------- 10---------J
  L------------------- 31 ------------J
```

Finally, Yerkish has a correlator expression for one more relation: similarity or difference, i.e., the relation resulting from the specific comparison of two items that may be perceptually present or purely representational.

33 sameness–difference marker / applied to / term of comparison

```
same-as                        water
  L---------------- 33-----------J
```

As is the case with the lexigram classes, we have not yet reached the maximum number of correlators foreseen in the present system. The computer program is designed for a maximum of 46 correlators. At present the system is operating with the 35 just listed (of which Lana's messages have so far involved 26) and with 3 more functions that handle the "sentential markers" for request, query, and negation. Thus we have eight more correlator slots that can be successively filled with new relational concepts as the progress of our subject and the requirements of future experimentation dictate.

YERKISH SENTENCE STRUCTURE

Given a basic list of correlators and their linguistic expression, the classification of lexical terms can be carried out by listing for each item the correlators that *potentially* can link it to other items. To give an example, there is a relational concept (Correlator 11) paraphrased as "active ingestion of solids, involving solid food as direct object"; on the linguistic level, this relation is expressed by the juxtaposition of two lexical items in a certain order. If we have the lexigram *eat*, which designates "active ingestion of solids," and another lexigram *raisin*, which designates a subcategory of "solid food," we can form a combination, or *correlation*, with the two lexigrams that can be represented as the structure:

```
        (LH)                           (RH)
(a)     eat                            raisin
         L----------------- 11-----------J
```

Because the order of succession of the two items in the linear linguistic expression is obligatory and cannot be reversed, it is not enough for the grammar merely to supply the information that the lexigrams *eat* and *raisin* can be linked by Correlator 11. 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 there by means of "correlation indices" (I_c's), which consist of the number of the potential correlator plus an indication which specifies whether the items to which this I_c is assigned can function as LH-piece or as RH-piece. Thus in Example (a) both *eat* and *raisin* can be assigned to Correlator 11, but *eat* would be assigned the correlation index I_c : 11-LH, whereas *raisin* would be assigned the correlation index I_c : 11-RH. Thus when either of these two words appear in any two-word phrase describing the concept defined by Correlation 11, *eat* will always have to be the left-hand member and *raisin* will always have to occupy the right-hand position.

In many cases, of course, several lexical items, all members of the same lexigram class, can function in the same place. Therefore, I_c's are actually assigned to lexigram classes, not to single lexical items. On the one hand, this indexing of classes rather than individual items is more economical with regard to storage space; on the other, it permits the addition of new lexigrams to the existing classes without in any way disturbing the operative part of the lexicon.

Let us add another correlation and expand Example (a). The relational concept paraphrased as "autonomous animate actor performing stationary activity" is Correlator 01. The paraphrase "autonomous animate actor" comprises three lexigram classes of the present lexicon, namely "familiar primates" (AP), "unfamiliar primates" (AC), and "nonprimates" (AO); it excludes the fourth "actor" class, i.e., "inanimate actor" (AM), or the machine. The paraphrase "stationary activity" comprises three lexigram classes, namely "ingestion of solids" (VE), "ingestion of liquids" (VD), and "relational motor activity" (VA). Given the lexigram sequence *Lana eat* the interpretive grammar finds that Lana, belonging to class AP, bears the I_c : 01-LH; whereas *eat*, belonging to class VE, bears the I_c : 01-RH; on the strength of these complementary indices the grammar will allow the correlation:

```
          (LH)                         (RH)
(b)       Lana                         eat
           └------------- 01 -----------┘
```

The grammar, it must be remembered, is an interpretive one, and its rules have been formulated in such a way that the automatic parser can apply them. Allowing a correlation, therefore, means that the parser in its progress from left to right along the input string of lexigrams records that correlation as a possible part-interpretation. It is recorded as a "product" in order to be tested for its potential correlation with other parts of the input string.

Correlations that link single lexigrams, such as Examples (a) and (b), can be made and checked on the basis of the I_c's assigned to each lexigram in the lexicon. In order to discover whether or not such a product can be correlated with other lexigrams of the input, each product must be assigned a string of I_c's that represents its individual potential for functioning as LH-piece or RH-piece in larger correlations that link it with other lexical items or products. The procedure that assigns I_c's to a given product is the dynamic part of the grammar. It is governed by *operational* rules that are rather complicated, since the correlability of a given product often depends on more than one of its constituents. An example will help to make this clear. Correlator 30 is paraphrased as "determiner applied to an item to be specified," and among the products it creates are phrases such as:

```
this                raisin          this                ball
 L---------- 30----------J    and     L---------- 30-----------J
```

With regard to Correlator 30, *raisin* and *ball* are identical pieces. But as potential RH-pieces of a larger correlation, one formed, say, by Correlator 11 (paraphrased as "ingestion of solids, involving as direct object a solid food"), they are not at all equivalent. The correlation:

```
eat                  this                 raisin
 |                    L----------- 30------------J
 L------------------ 11----------------------J
```

would be acceptable, whereas the correlation:

```
eat                  this                 ball
 |                    L----------- 30-------------J
 L------------------ 11
```

would *not* be acceptable because *ball* does not belong to the lexigram class EU (defined as "solid food") and therefore is not a potential RH-piece of Correlation 11. For this reason if the string *eat this ball* occurs as input to the interpretive grammar, it must be rejected as incorrect. To implement this discrimination, the phrase *this raisin* must be assigned I_c : 11-RH, but the phrase *this ball* must not. In other words, before any product made by Correlator 30 can be assigned the I_c : 11-RH, it must contain as its right-hand piece an item that belongs to the lexigram class "solid food."

In the implementation of the parser, as the preceding example demonstrates, the assignation of I_c's to products has to be determined not only by the specific correlator responsible for the product to be classified but also by the pieces that the product contains. The conditions these assignation rules express vary for each correlator, and many products require the application of more than one rule. This, indeed, is the reason why an interpretive correlational grammar cannot be represented by means of a small set of powerful, generalized rules. Thus it might seem that correlational grammar would be a much less economical approach to the analysis of language than the relatively concise formalizations of some other modern grammars. Closer examination, however, shows that this is not so. Generative–transformational grammar, for instance, when used for the purpose of interpretation requires a vast number of selection rules in order to deal with the very same *semantic* information that is involved in our assignation rules. Applied to the preceding example, a generative grammar would allow the string *eat this ball* on the basis of the syntactic classification of the words it contains, but would subsequently eliminate it as incorrect on the basis of specific selection rules. Since the rules governing syntactic connections and the rules governing semantic selection operate in different ways and with altogether different classifications, an automatic parser using that kind of grammar must continually shift back and forth between the syntactic and the semantic ways of operating. The difference is simply this: In correlational grammar these rules are incorporated in one homogeneous correlation procedure, whereas in all syntax-based grammars they constitute an unwieldy adjunct of functionally different accessory procedures that tend to consume more and more space and time as their operational implementation is improved and completed.

PECULIARITIES OF THE YERKISH GRAMMAR

The grammar of Yerkish had to be kept as simple as possible for several reasons. Most importantly, the rules of the language to which the linguistic behavior of our subject would have to conform had to be few and consistent from the learner's point of view; nevertheless the Yerkish structures built upon them had to be translatable easily and without major structural changes into comprehensible English. As a result, Yerkish grammar may seem somewhat unusual. In the following paragraphs, the more salient deviations from English grammar will be explained.

Yerkish at present has only one voice, the active, and three moods:

indicative, interrogative, and imperative. Both the interrogative and the imperative are formed not by specific verb forms or word order as in many natural languages but by sentential prefixes, or markers. The prefix of the interrogative is the conventional question mark "?"; that for imperatives (requests) is an arrow translated into English as "please." The keys representing these lexigrams must be pressed at the beginning of a string. The lexigram string following them always has the form of an indicative statement even when it constitutes a command or a question. If the string is actually to be interpreted as an indicative statement, it must not be preceded by either "?" or *please*. Hence we have:

Tim move into room.	=	indicative statement
? Tim move into room.	=	interrogative (query)
Please Tim move into room.	=	imperative (request)

A third lexigram that functions as a sentential prefix is *no*, which corresponds to an overall negation of the statement.

No Tim move into room. = negation

This last sentence corresponds to the English "It is not the case that Tim moves into the room." However, since Lana has spontaneously come to use the lexigram *no* to mean what, given the situational context, can only be interpreted as "don't", this *no* is now allowed to function also as the negative imperative.

As yet, there are no tenses in Yerkish except the present. A simple past and future are foreseen, and when in use they will be designated by particles preceding the activity lexigram in the string. These particles will function as auxiliaries, which at present Yerkish does not possess. The English linking verb "to be" is taken over by Correlator 10, which is expressed by the juxtaposition of a lexigram belonging to one of the classes of items that are modifiable and a lexigram designating a specific state or property. For example

Ball red.	=	'The ball is red.'
Tim here.	=	'Tim is here.'

The absence of an explicit linking verb is noticeable also in conjunction with the "naming function," an important instrument in Lana's acquisition of new lexical items. It is used together with the ostensive definition of new lexigrams, which are placed at the beginning of a string of the form:

X name-of this. = 'X is the name of this,'

where X is the new lexigram. The same sentence structure can be turned into a question:

? What name-of this.	=	'What is the name of this?'
? What name-of visitor.	=	'What is the name of the visitor?'

The lexigrams *this* and *visitor* are the only ones that are permissible in this question because any other lexigram would preempt what is being asked for. Strings such as: *? What name-of Tim* already contain the lexigram for which the question asks and therefore make no sense.

Two English constructions that have a specificative and restrictive function, "the red ball" and "the ball which is red," are one and the same in Yerkish. The specificative relation is expressed by a lexigram which is translated into English as the compound *which-is* (Correlator 31). Example:

Ball which-is red.	=	'the red ball' or 'the ball which is red.'

Spatial prepositions in Yerkish were originally strictly divided into locational and directional categories (lexigram classes LP and DP). However, since Lana has spontaneously used *behind* and *outside* (both classified as "locational") to indicate the target of a directional activity and since this usage is also allowable in English and other natural languages, we have removed the restriction with regard to these two prepositions.

Until recently there were no conjunctions in Yerkish, but a somewhat restricted form of "and" is now ready to be introduced into the system. Two actors of one and the same activity can be linked by the Yerkish *and*, and so can two direct objects. Thus, we now have sentences such as:

Tim and Lana eat.
Lana drink juice and water.
Please Tim give ball and M&M.

But the parser will reject sentences such as:

**Lana drink juice and banana.*
**Please Tim give ball and machine.*

Owing to the restricted workspace in the computer, we have not attempted to design control routines for phrase and sentence conjunction. The system, therefore, cannot as yet handle expressions such as, *Tim drink coffee and Lana eat piece of chow.*

This last example brings to mind a deliberate peculiarity of Yerkish grammar. The classification of lexigrams makes a distinction between "edible units" and "edible materials," a distinction that makes little sense to an English-speaking person (see the explanation on page 99). However, it results in the use of two rather different sentence structures according to the type of "solid food" that is mentioned. The items designated by lexigrams of class EU, for instance, can be asked for as wholes whereas items designated by lexigrams of the class EM can only be obtained one piece at a time. Thus, the computer will honor the requests:

Please machine give M&M.

and

Please machine give piece of chow.

But not

**Please machine give piece of M&M.*

or

**Please machine give chow.*

This distinction is a rigid rule for the computer, since the automatic dispensers can handle only pieces of chow, apple, banana, etc. In requests addressed to Tim or other human companions Lana can of course request:

Please Tim give apple.

Yerkish also contains some minor peculiarities that an English-speaking person must keep in mind. A Yerkish structure involving Correlator No. 17 (change of hands, involving as direct object a handable item) implies that the speaker is the receiver of the item that changes hands unless another receiver is explicitly indicated by a prepositional phrase. Thus, if Lana produces the string:

```
Please          Tim     give          milk.
  |              |       L------ 17 ------J
  |              L------ 05 ---------J
  L--------------------------J
```

it must be understood that the milk is to be given to Lana. But a receiver can be explicitly specified by adding a prepositional phrase, which yields the correlational structure:

```
Please          Tim   give          milk   to          Lana
  |              |     L----- 17 -----J     L----- 22 -----J
  |              |            L--------- 21 ---------J
  |              L-------- 05 ----------------J
  L------------------------------J
```

English "resultative" verbs (e.g. "to open" and "to clean") are broken up in Yerkish. The causative element is rendered by *make*, and the effect by a lexigram designating the resulting state or property. Also, in Yerkish these constructions require that the agent be specified. Thus, *Please (Tim) open the window* becomes:

```
Please          Tim   make   window      open.
  |              |     |       L----- 10 -----J
  |              |     L------- 18 -------J
  |              L- 06-------------J
  L---------------------J
```

Translated literally into English, this string should read 'Please, Tim, make (the) window be open,' since the correlator that links *window* and *open* is Correlator 10, i.e., the *predicative* relation equivalent to what is expressed by the English "to be." In this case as in most occurrences of Correlator 10, the Yerkish string is easily understood without the explicit linking verb.

The Yerkish *make* is not limited to causing a change of state of specific items but can be used also to indicate a number of perceptual conditions or events in the environment. Specific sensory events such as *movie, music, slide, heat, cold*, and *light* are considered the result of activities subsumed by *make*. In Lana's wholly technological environment this use of *make* is quite reasonable. It obviously makes sense for her to request, for example:

```
Please        machine   make        movie.
  |              |        L------ 13-------J
  |              L---- 06-------------J
  L----------------------J
```

It is, indeed, the machine that causes the projector to start running. Similarly, in Yerkish one can correctly say:

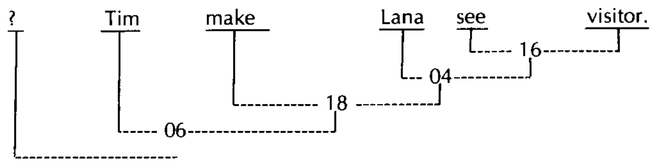
```
Please          Tim   make   less         heat.
  |              |     |       L-------- 30 -------J
  |              |     L------- 18 -------J
  |              L- 06--------------J
  L---------------------J
```

In Lana's experience, it is in fact Tim who causes less heat by turning down the thermostat. This kind of request, however, has not yet been made by Lana.

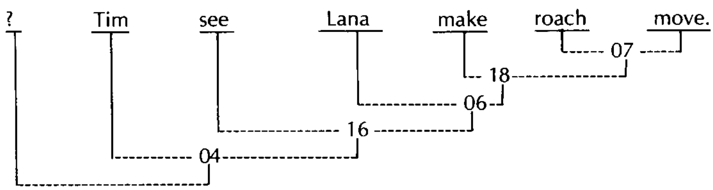
Make and *want* open the way to "embedded" constructions, since they can govern clauses. A simple example of embedding is:

```
?     Tim       make   machine       give        Coke.
|      |          |       |            L------- 17 ------J
|      |          |       L----------- 05-------------J
|      |          L---------- 18 -----------J
|      L------- 06-----------------J
L-----------------------
```

Once lexigrams of class VP ("perceptual activities") have been introduced, there will be embeddings of the kind:

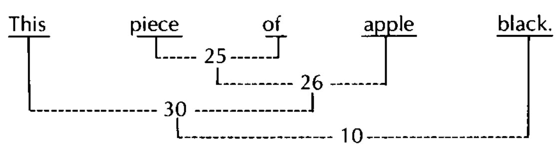


and even double embeddings such as:

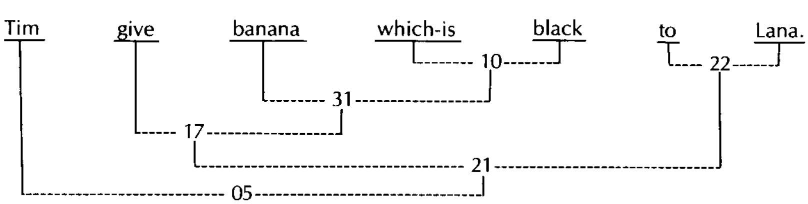


At this time, however, the lexigrams for "to see" or "to hear" have yet to be introduced and therefore Lana cannot produce sentences that contain this type of embedding.

Lest these correlational diagrams create the impression that Yerkish structures are invariably right-branching, here are two examples that contain left-branchings:



which in English would read: "This piece of apple is black," and likewise:



Though the examples of Yerkish sentence structure given in these pages are few, they should convey some idea of the versatility and flexibility of this wholly automated grammar, especially if they are considered in conjunction with the lists of lexigram classes and of correlators discussed earlier. Lana has made spectacular progress in her mastery of the linguistic communication facility. Nevertheless, Yerkish grammar as it stands allows many constructions that are still far beyond Lana's reach. The area of "embedded" phrases has only been touched upon, and Lana has not yet been introduced to the lexigrams designating perceptual activities (class VP), which would at once lead to a variety of complex sentence structures. The operational lexicon at this moment is approaching 100 items, or 40% of the system's capacity. Nine more lexigram classes and eight more correlators could be added at a moment's notice without any alteration of the procedures and programs that constitute the automatic parser. In short, although Lana has proven to be an extremely quick and responsive pupil, the teaching system is still a good bit ahead of her.

THE MULTISTORE PARSER

There are two reasons why an automatic parser capable of monitoring all linguistic transactions was included in the Yerkes communication facility. The first was our wish to create a training environment that would be operative at least partially for 24 hours a day without the need of permanent human attendance. Therefore, the system had to be able to respond to certain requests automatically. In order to do so, the system had to be able to understand these requests at least to the degree that it could discriminate those to which it was supposed to respond from those to which it was not. The second reason was that the system would need to provide an objective grammatical analysis of all the linguistic input produced by the experimental subjects. The first of these objectives could have been attained by a crude and relatively simple system of tags or code signals that would have had nothing whatever to do with *language*. But since the second objective in any case required the installation of a comprehensive parser of Yerkish lexigram strings, the obvious solution was to make the system's automatic responses dependent upon the sentence analyses provided by the parser. The sophisticated electromechanical interface between the computer and the various devices it can command in response to certain linguistic requests is discussed elsewhere in this volume (see Chapter 7). In this section, therefore, I shall try to give a brief outline of the parsing *procedure*; the computer program that implements this procedure is described in the next chapter by Piero Pisani, who collaborated in developing the Multistore parser since its first implementation 13 years ago in Italy and without whom it would never have become an operational system.

The parser of the Yerkes facility is a direct but drastically reduced derivative of the Multistore parser for English sentences (von Glasersfeld & Pisani, 1968, 1970). The rate of reduction can be illustrated by two comparative indications: The parser for English operated with some 500 correlators, whereas the grammar of Yerkish operates with 46. The original Multistore system occupied over 200,000 machine words in the largest computer that was available in 1968; the automatic parser of Yerkish is implemented in a central core area of about 2500 machine words in what can almost be called a minicomputer.

Input to the system is provided by means of a keyboard containing at most 125 lexigram keys arranged in panels of 25 each. Four such panels are in use at present, making a total of 100 keys and lexical items. The parser, however, can handle a lexicon of 250 items. Since the keyboard panels are readily exchangeable, the operational lexicon could be extended to the parser's full capacity of 250 by preparing 10 keyboard panels and using different subsets of five on different days or during different sessions.

When a key in the keyboard is pressed, it activates the corresponding lexical item in the machine's permanent lexicon, provided the system has been switched on. It is switched on by means of a horizontal bar mounted above the keyboard which has to be pulled down and held down throughout the input of a message. A message is composed by pressing several keys in succession and is ended by pressing the "period" key. This end-signal is essential for the computer because the grammaticality of a string can be established only when the string is considered complete by the sender. Many strings contain parts which, if they were taken as wholes, would not be grammatically correct messages. For instance *Please machine give* is not an acceptable statement in Yerkish because *give* is a transitive activity word that requires specification of what is given, but *please machine give juice*, where *juice* specifies the direct object of the activity, is a grammatical utterance.

In the machine's lexicon, the lexigram entries are ordered according to the conceptual classification of the items the lexigrams designate. If a lexigram key is pressed, a code signal travels to the machine's lexicon and "activates" the corresponding entry. Let us assume that this entry is *Tim*. Activation of a lexicon entry has several immediate effects. First, the lexigram code is passed on to the output printer which types out the corresponding English word, in this case the name "Tim." Second, a new code signal emanates from the particular lexicon area in which the activated entry is located and which represents the *lexigram class* to which it belongs. This new signal activates the particular line in the central Multistore area, i.e., the workspace of the machine, where the I_c string that characterizes that lexigram class is recorded. A diagram showing how I_c strings are recorded in the

Multistore area may be helpful in visualizing how the procedure functions. The Multistore area can best be imagined as a rectangular arrangement with 46 horizontal lines, one for each of the 46 lexigram classes, and 46 columns, one for each of the 46 correlators foreseen in this implementation of the system (see Figure 1). Since the l_c's assigned to lexigram classes indicate not only the numbers of the correlators by means of which items of that class can be linked to other items but also the place (LH or RH) the items take in the particular correlation, the l_c columns in the Multistore area are all subdivided into an LH-column and an RH-column. The lexigram *Tim*, for example, belonging to class AP, activates a total of 13 LH-markers and 10 RH-markers in the Multistore area. In Figure 1, in which only six correlators are specifically indicated, the lexigram *Tim* is represented by the LH-markers of Correlators 01, 02, and 03.

If the key for *drink* is pressed after the key for *Tim*, the result will be the activation of those markers that represent the l_c string assigned to the lexigram class VD on the line of that class in the Multistore area. In the diagram, these would be the RH-marker in the column of Correlator 01 and the LH-marker in the column of Correlator 12.

If now the "period" key is pressed, the machine will scan the Multistore area and will discover that in column 01 there is an LH-marker on line AP and an RH-marker on line VD. The mere presence of LH- and RH-markers in a correlator column, however, is not yet sufficient for the machine to produce a correlation. It must also check whether these two markers were entered in the proper sequence, i.e., whether the LH-marker originated from a lexigram that actually came first and the RH-marker from a lexigram that followed immediately after that first one. The order of input is, of course,

Lexigram class	Correlators														
	01		02		03		...	12		...	16		...	46	
	LH	RH	LH	RH	LH	RH		LH	RH		LH	RH		LH	RH
AP (L_1)	×		×		×							×			
⋮															
VD (L_2)		×						×							
⋮															
Class 46															

Figure 1. Diagram of the Multistore lexicon. For each l_c in the l_c string characterizing a lexigram class, there is a marker in the Multistore cell that is the intersection of the line representing the lexigram class and the column representing the correlator indicated by that l_c. The marker further indicates whether members of the particular class can function as LH- or RH-pieces in correlations represented by that column.

recorded at the same time as the activation of the markers, and I have indicated it in parentheses at the beginning of the individual lines of the diagram (L_1 = lexigram 1, etc.).

The most general rule of a correlational parser is very simple: Whenever successive entries result in the activation of first an LH-marker and then an RH-marker in *one* I_c column, the two input items represented by these markers can be correlated by the correlator indicated on top of the column in which the markers are found. Thus, if the lexigrams *Tim* and *drink* were followed by the "period" sign, the machine would accept these two words as a grammatical utterance and would assign to it the structure:

```
Tim                            drink
 L------------------ 01 -------------------J
```

If instead the input continued after the lexigram *drink* with the lexigram *water* and only then the "period" key were pressed, there would be combinable markers also in column 12. Since the scanning procedure follows the order of input, the machine would first discover the possibility of making a correlation in column 01, just as it did in the preceding case. It would, indeed, "make" this correlation, and it would record it as a "product," indicating that the product consists of lexigram L_1 and lexigram L_2 and is linked by Correlator 01. At this point it would interrupt its scanning of the Multistore columns and would switch to the "reclassification routine," i.e., the procedure by means of which I_c's are assigned to products (see page 113).[7] This reclassification routine always consists of one or several of three basic types of rules, each one of which determines whether or not a specific I_c of a set that is preestablished for each correlator is to be assigned to the product in hand. The first type simply assigns a given I_c unconditionally to the product. The second type assigns a given I_c if the LH-piece (or in other cases the RH-piece) of the product had that same I_c in its string. The third type assigns a given I_c only if two conditions are satisfied. At present only one Yerkish construction requires this rule: the conjunctive relation implemented by Correlator 35. The dual condition for the assignation of a given I_c in this case is that both the LH-piece of the product and the RH-piece of the product's RH-piece have that I_c in their strings.

The reclassification routine, in fact, inserts the product that is being reclassified into the Multistore area as though it were an input item and activates LH- and RH-markers in the line on which the product is recorded.

[7] In different implementations of the Multistore parser the point in the operational flow at which products are reclassified has not always been the same. One version of the Yerkish parser, for example, scans for and records all products arising after input of a new lexigram and only then begins the reclassification of these products.

When the reclassification of a product has come to its end, its line has exactly the same form and function as the line of an input lexigram; the only difference is that at the beginning of the line instead of the input-number of a lexigram, there is the indication that it is a product and a record of the lexigrams or products it consists of.

In our example, then, after the key for the lexigram *water* and the "period" key have been pressed, the part of the Multistore area that is operative in the analysis of the input lexigram sequence would appear as shown in Figure 2.

The reclassification of Product 1 is such that no correlation can link it to lexigram L_3, once that has appeared in input. Lexigram L_3, however, produces a correlation with L_2 in the column of Correlator 12, and the reclassification of this product (Product 2) activates an RH-marker in column 01. This gives rise to Product 3, which, since the "period" key has now been pressed, constitutes the final product that comprises all the lexigrams of the input. This product has the structure:

```
Tim                         drink                   water
 |                            |------------ 12 ----------|
 |------------------ 01 ----------------------|
```

The procedural description of this example should make it clear that the Multistore parser embodies a system of *analysis by synthesis*. Whenever a lexigram is added to those that have already been put in, the machine searches for and actually makes all the "products" that are permissible according to the grammar at that point. Some of these products will be dead ends in that they cannot be incorporated into larger ones when the subsequent lexigrams of the input are considered. They constitute side branches of the path that seeks a correlational structure linking *all* the lexigrams of the given input sequence.[8] When such a comprehensive structure is found at the point when the period key has indicated that the input sequence is finished, this structure is a "final product," and the fact that it *could* be found demonstrates that the input was a *grammatical* sequence.

Since both the Yerkish lexigrams and the Yerkish grammar were specifically designed to avoid ambiguity, we have at present no cases in which

[8] This exhaustive construction of all *possible* grammatical part-structures within an input sequence differentiates computer interpretation from human interpretation. Whereas the human interpreter proceeds on the basis of situation-bound expectations, computers have so far always had to proceed on the basis of theoretical rules that do not take into account the pragmatic context of an utterance. Analysis and classification of the living-experience from which our expectations arise has begun only recently (e.g., Schank, 1972, 1973, 1975), and the procedures and data base such analysis would require is, in any case, far beyond the capacity of a small computer.

Lexigram class	Correlators														
	01		02		03		...	12		...	16		...	46	
	LH	RH	LH	RH	LH	RH		LH	RH		LH	RH		LH	RH
AP (L_1)	×		×		×							×			
⋮															
VD (L_2)		×						×							
⋮															
Product 1 L_1-01-L_2												×			
⋮															
ED (L_3)									×			×			
⋮															
Product 2 L_2-12-L_3		×													
⋮															
Product 3 L_1-01-P_2												×			

Figure 2. Diagram of Multistore area after input. The diagram shows all markers activated by the input lexigrams *Tim, drink,* and *water,* and by the products that arise from these lexigrams. The dotted lines connect the complementary markers in the correlator columns that give rise to products.

the parser could possibly come up with more than one final product for a grammatical input sequence. It is unlikely that this univocality will be preserved when more correlators and conceptual lexigram classes are added. By then, however, we anticipate that Lana will have a firm enough grasp of the principles of communication (e.g., the principle that any communication requires a context for its interpretation) to resolve such ambiguities as may crop up in Yerkish by reference to the situational context in which they occur. For the present, the absence of ambiguities in Lana's messages is an enormous advantage: Because of it the question of appropriateness can almost always be decided definitively by the observer. If her utterances could be correct and at the same time interpretable in more than one way, it would often be quite impossible to determine which interpretation was really the one she intended.

It is important to emphasize that the parser's verdict of correctness is based exclusively on the grammar. The parser, that is, establishes the grammaticality of an utterance, not its appropriateness in a given situation. Appropriateness can be assessed only on the basis of situational context, motivation of the communicator, and effects of the communication on the receiver—none of which, in view of the present state of computer science, can be perceived by a computer.

To conclude this brief and necessarily superficial description of the parsing procedure, I would like to stress that many of the present restrictions of Yerkish grammar do not result from the nature of correlational grammar, nor from limitations inherent in the multistore system, but exclusively from the fact that we are working with a very small computer, and, therefore, have space only for the most elementary interpretive algorithms. At the outset of the project, we decided that the automatic parser, including the operative lexicon of 250 lexigrams, should be contained in a central core area of no more than 5000 machine words. To anyone familiar with computers it will be clear that this limit necessitated a quite extraordinary compression of data. In fact, we were able to succeed only by exploiting every single "bit" of that core and by using the method of "significant address," which had been developed during our work on the Multistore parser for English sentences. Figures 1 and 2 illustrate, at least in a superficial way, how the data compression was achieved: The formal similarity between the lexicon area and the operational Multistore area in which correlations are produced indicates that the two are, in fact, located in the same area of the computer's central core. The two data structures are superimposed one on the other in that area. This layering of data structures and functions will be described in greater detail in the next chapter; here I have presented only an outline of the procedure that enables the computer to decide whether or not a given input sequence of lexigrams is grammatical.

THE GRAMMATICALITY OF LANA'S SENTENCE PRODUCTION

The automatic parser is one of the features that make the Yerkish communication project different from other efforts at communication with nonhuman primates. Because the computer records every linguistic transaction while the Multistore system assesses every input sequence to determine whether or not it conforms to the preestablished grammar, a data base is created, which can be analyzed in many ways. To illustrate one of these possibilities, I shall here summarize some of the results that emerged from a study of Lana's sentence production during the month of September 1974.

The only aspect with which I was concerned in that study was grammaticality. Specifically, how many of the lexigram sequences produced by Lana showed a correct correlational structure and how many did not. This way of looking at the performance of a language user is what linguists call "assessing syntactic competence." From the point of view of the ordinary human language-user (who uses language as a means of communication in order to achieve certain results in or through the receiver) it is, of course, quite absurd to single out syntactic competence as the all-important criterion of linguistic proficiency. A great deal of our daily linguistic production is syntactically faulty or incomplete, but nevertheless it generally achieves our communicatory purposes, and even when it does not, the failure is only very rarely due to *syntactic* deficiency. I emphasize this fact so that the results derived from this survey of Lana's production record will not be construed as evidence of her *communicatory* competence. These results are derived from the automatic records of Lana's messages and therefore do not take into account whether or not the individual messages were appropriate to the contexts in which Lana composed them on her keyboard. All they show is that Lana has in some way acquired the capability of producing lexigram sequences that conform to the grammar of Yerkish much oftener than they would if they were assembled randomly.

The terms "type" and "token" are indispensable in such an analysis of sentence production. "Types" are defined as individually different lexigram sequences, and "tokens" are defined as the occurrences of one and the same "type." Consider the following list of sample sentences: *Lana drink milk, Lana drink juice, Tim drink milk, Machine give juice, Machine give juice to Lana*. In this list there are five "types" each represented by one "token" (i.e., one occurrence of a type). The list *Please machine give juice, Please machine give juice, Please machine give juice*, on the other hand, contains but one "type" represented by three "tokens."

Discriminating between types and tokens is of the utmost importance if we want to discuss whether Lana's production of grammatical lexigram strings can be explained by the conventional theories of conditioning or requires the assumption of some kind of rule-learning.

All theories of conditioning by reinforcement are based on the principle that a behavior "response" is more likely to recur if it is reinforced. In order to be reinforced, however, a behavior must occur at least once, for it is obvious that nothing can reinforce an organism for "emitting" a behavior which that organism has not yet emitted. Applied to verbal or key-pressing behavior this principle means that, though we can condition our subject to produce more and more tokens of the types we reinforce, we cannot condition her spontaneously to produce *types that are both novel and grammatical*. (Even training for the production of novel behaviors alone is difficult and requires a great deal of time and patience both on the part of trainer and trainee; cf. Bateson, 1972, p. 276.)

Table 3 shows a breakdown of Lana's production of four-, five-, and

Table 3
LANA'S SENTENCE PRODUCTION DURING SEPTEMBER 1974

	Errors		Grammatical strings					
					Computer reinforced		Other strings	
Length of string	Types	Tokens	Total types	Total tokens	Types	Tokens	Types	Tokens
4 lexigrams	80	98	76	2756	4	2664	72	92
5 lexigrams	91	101	152	738	3	315	149	423
6 lexigrams	71	84	125	1577	4	1288	121	289

six-lexigram strings during the 1-month period. They are divided into grammatical and ungrammatical strings, and in each group the number of types is given as well as the number of tokens.

In September 1974 Lana's keyboard consisted of 3 panels of 25 lexigram keys each. Thus the keyboard contained 74 lexigrams plus the "period" key. Since we have no computer program that can generate all possible grammatical strings of, for example, 4 lexigrams from a lexicon of 74, I cannot say precisely what percentage of the 30×10^6 random combinations Lana's keyboard could theoretically generate from four lexigrams would be grammatical. (The strings we are talking about, regardless of whether they are grammatical or not, are, of course, types, not tokens.) On the basis of a manual compilation of the grammatical 2-, 3-, and 4-lexigram strings that can be made from a lexicon of 49 lexigrams using the same grammar, I know that the grammatical strings would amount to approximately 15%, 1.7%, and .2%, respectively of all possible combinations. Without knowing the actual figures, therefore, we can say that the percentage of grammatical strings decreases quite drastically with the length of the string. At the 6-lexigram level it is safe to assume that no more than one out of 10,000 randomly combined strings will be grammatical.

Since the proportions of ungrammatical to grammatical strings in Lana's record are 80:76, 91:152, and 71:125 for 4-, 5-, and 6-lexigram strings, respectively, Lana clearly demonstrates a strong tendency toward grammaticality. This should not surprise anyone, because the reinforcement she received was always contingent upon the grammaticality of the strings she produced. Thus, on the face of it, her performance is just one more confirmation of reinforcement theory.

If we look at the actual strings she produced, however, we get a very different picture. As an example, let us take the 6-lexigram strings. (The figures are roughly the same for all three groups.) Of the 125 grammatical types in this group, 4 are requests for food to which the computer automatically responds (e.g., *Please machine give piece of chow*). These four types account for 1288 tokens. Lana was deliberately trained to produce them, and she has consistently used them to nourish herself. Of the remaining 289 tokens, 61 are answers to questions which were part of an experiment testing Lana's proficiency in the use of color terms, and they represent 45 types. Since some of these answer types were produced as a result of task-specific training, I shall disregard this group even though many of these types were spontaneously produced novel strings. We are now left with 76 other types of which Lana produced 228 tokens. Nearly all of these types are sentences Lana used to ask for something or someone to move or be moved in or out of her room, or to ask that food or drink be moved *behind room* (by which phrase she came to indicate the automatic dispensers). None of these types were produced as the result of training; they were all spontaneously formulated by Lana. Once they *had* been formulated, they were no doubt reinforced by being answered, and that accounts for their repetition (e.g., 36 tokens of *? You carry Lana out-of room and* 34 tokens of *? You move chow behind room*). Their first occurrence, however, was not only a spontaneous production each time but also in some cases a rather imaginative transference of a meaning acquired in a very specific context to a context that was substantially different.

To conclude this survey of Lana's production, we must ask two questions. First, how can we explain the fact that Lana composed on her keyboard 76 strings of 6 lexigrams that were grammatical sentences and that did not figure in any training program, whereas during the same period she produced only 71 6-lexigram strings that were ungrammatical? Second, how can we explain the fact that Lana's error rate showed no increase as the lexigram strings she produced got longer? Both phenomena could be interpreted as the result of Lana's acquisition of a small number of rules. But the mere assumption of rule-learning does not really explain anything; it only introduces a new term for an unobservable process. The important factor, I believe, is this: The Yerkish language and its grammar were deliberately based on conceptual lexigram classification and conceptual connectives. Therefore, the rules that have to be learned to produce grammatical structures in Yerkish are not purely linguistic rules, but rules that are relatively close to the rules that govern conceptual representation. The chimpanzees at Reno, at Santa Barbara, and in Oklahoma, as well as Lana, have all shown that they can operate on the symbolic-representational level. If they indeed can, the grammaticality of Lana's Yerkish production, her creation of novel strings, and the constancy of her error rate (her errors were caused by distraction and "typing errors" rather than incapacity) are not really surprising. Once she had acquired the "names" for objects and for certain relations, the grammatical structure of sentences in most cases was merely a reflection of the structure of her representations.

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