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Origins and development of contemporary syntactics

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Abstract.

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This paper reviews the literature of semiotic theory from the mid-19th century to the present. It presents a careful reading of the works of logic-oriented semioticians, Rudolf Carnap and Charles Morris, linguistics-oriented semioticians, Ferdinand de Saussure and Luis Hjelmslev, and outlines David Hilbert's metamathematics, Noam Chomsky's generative grammars, as well as contemporary computational linguistics and their influence upon contemporary syntactic theory. It redefines the three disciplines of semiotics — syntactics, semantics, and pragmatics — as studying the three factors of semiosis from differing points of view, and introduces three classes of syntactics.

Semiosis is the process in which something functions as a sign. Syntactics is that branch of Semiotics that studies the formal aspects of signs, the relations between signs, and the combinations of signs. In order to understand what is covered by this characterization, one has to consider Syntactics in the context of the other branches of semiotics, which are usually defined with respect to its subject matter, semiosis. Different semioticians distinguish different factors in semiosis; compare for example the traditions of Peirce [65], Morris [57-59], and Carnap [12-14]; of Saussure [80], Buyssens [9], Hjelmslev [39], Prieto [72]; of Ogden and Richards [61], Bühler [8], and Jakobson [42]; and of Uexküll [90]. However, all such structurings of semiosis involve at least three factors, whose interrelation is described by phrases such as: A takes B to stand for C, B refers to C for A, A takes account of C by virtue of the presence of B, etc. We therefore stipulate that the following is a necessary and sufficient condition for something to be a semiosis:

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A interprets B as representing C.

In this relational characterization of semiosis, A is the interpreter, B is some object, property, relation, event, or state of affairs, and C is the meaning that A assigns to B. These factors are connected by the triadic relation : ... interprets ... as representing .... The term *sign* can be used in two different ways with respect to this relation. While logic-oriented semioticians like Morris and Carnap use it as a term for B's, linguistics-oriented semioticians like Saussure and Hjelmslev use it as a term for pairs of B's and C's. The latter usage is justified by the fact that what meaning is assigned to some entity in a specific semiosis depends in part on properties of that entity.

However, meaning also depends on properties of the interpreter: It is true for all three ranges of entitites that can enter the three slots in the triadic relation that they are dependent on each other. In the rest of this article a separate term for each of the three factors is used: A is referred to as an interpreter, B as a sign, and C as a meaning.
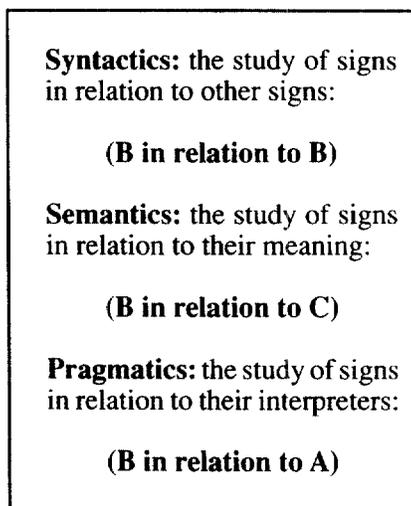
Syntactics, semantics, and pragmatics

Because of the interdependence of the three factors it is not easy to devise a clearcut division of labor for the investigation of semiosis. Nevertheless, a tripartite division of semiotics is now generally accepted. It is usually defined with regard to the three factors of semiosis. The conditions an entity must fulfill to be able to represent meaning for interpreters in semiosis are the subject matter of syntactics. The conditions an entity must fulfill so that it can be represented by signs for interpreters in semiosis are the subject matter of semantics. The conditions an entity must fulfill to be able to interpret signs as representing meaning in semiosis are the subject matter of pragmatics.

The historical origins of these disciplines can be traced back to the artes dicendi, namely, grammar, rhetoric and dialectic, the teaching of which was organized in the so-called trivium in medieval European schools from the ninth century A.D. onward. Charles S. Peirce reinterpreted the artes dicendi as branches of semeiotic and systematized them as disciplines treating signs as Firstness, Secondness, and Thirdness, respectively. He distinguished between speculative grammar, critical logic - the successor of dialectic --, and methodutic -- the successor of rhetoric [65(§1.91 ff., 2.93)]. It was Charles W. Morris who coined the terms syntactics and pragmatics and introduced the division of semiotics into syntactics, semantics, and pragmatics [57]. Although this trichotomy is related to that of Peirce, its introduction was motivated differently: Morris tried to show that the objectives of three leading philosophical movements of his time, logical positivism, empiricism, and pragmatism, were not antithetical but complementary, since logical positivism studied the formal structures of the languages of science, empiricism studied the objects of research and their relations to the languages of science, and pragmatism studied the procedures and conventions governing communication among scientists [55,56]. Thus, for Morris, syntactics could utilize the methods and results of logical syntax developed by the logical positivists (as in Carnap [11]), while semantics and pragmatics could proceed from the analytical achievements of Empiricism and Pragmatism, respectively.

Despite their general acceptance, the theoretical status, the delimitations, and the subdivisions of the three branches of semiotics are still controversial today In *The Encyclopedia of Unified Science*, Morris treats the three branches in a parallel way [57]. He isolates the three factors of semiosis and specifies the subject matter of each semiotic discipline on the basis of a dyadic relation between one of the factors and the sign.

Since these three definitions do not cover all aspects of semiosis (e.g., the triadic relation between A, B, and C) and of semiotics (e.g., the problem of the interrelation of the three semiotic disciplines), all remaining aspects are said to fall under semiotics proper. In this conception, pragmatics cannot treat much of the relation between signs and interpreters without including meanings, that is, without becoming semiotics proper. This and other criticisms made Morris give up the parallel conception of the three branches in favor of a hierarchical one proposed by Carnap in his 1942 *Introduction to Semantics* [13].

Syntactics: the study of signs in relation to other signs:

(B in relation to B)

Semantics: the study of signs in relation to their meaning:

(B in relation to C)

Pragmatics: the study of signs in relation to their interpreters:

(B in relation to A)

Figure 1. Morris' branches of Semiotics

As Morris emphasized [cf:58(218f–219),60(302); cf:57(16),60(30–31)], Carnap's exposition can be adopted if it is generalized in a number of aspects:

> **Semiotics** not only deals with linguistic expressions but with all kinds of signs; therefore *language* has to be replaced by *sign system.*

> **Pragmatics** has not only to do with users and uses of signs in the sciences but with all kinds of sign users and sign uses.

> **Semantics** does not only treat the designative mode of sig-nification but all ways of representing meaning and all kinds of meaning.

> **Syntactics** not only comprises the logical syntax of the languages of science but is much wider, including:

> • phonology and morphology of the languages of science

> • phonology, morphology, and syntax of other languages

> • the analysis of the formal aspects of nonlinguistic sign systems

The result of this generalization was formulated by Morris in the glossary of his 1946 book [58(352ff.),60(365ff.)]:

> **Pragmatics** is *that branch of semiotic which studies the origin, the uses, and the effects of signs.*

> **Semantics** is *that branch of semiotic which studies the sig-nification of signs.*

> **Syntactics** is *that branch of semiotic that studies the way in which signs of various classes are combined to form compound signs. It abstracts from the signification of the signs it studies and from their uses and effects."*

Whereas Carnap had made syntactics seem to be the basis of all semiotic studies in 1934 [11] and Morris had treated syntactics, semantics, and pragmatics as relatively independent of each other in 1938 [57], they later tended to see syntactics as embedded in semantics and semantics as embedded in pragmatics [12(16),15(219ff.)]. This and the fact that Morris [58] avoids speaking of abstraction in his characterization of pragmatics (and semantics) have led some of his exegetes to speak of Morris' pragmatically unified semiotics [1] and to advocate the identification of semiotics with pragmatics. However, this would substitute a maximalist conception for the minimalist conception of pragmatics in Morris in 1938 [57] and was clearly not the intention of Morris or Carnap at any time of their lives [69].

It is not always easy to apply the term syntactics to the traditional problem areas of semiotics and to decide whether they are included within syntactics or not [cf:58(219–220),60(303)]. In many cases, the answer will be different according to which conception of syntactics it is based on.

If we are analyzing a language, then we are concerned, of course, with expressions. But we need not necessarily also deal with speakers and designata. Although these factors are present whenever language is used, we may abstract from one or both of them in what we intend to say about the language in question. Accordingly, we distinguish three fields of investigation of languages. If in an investigation explicit reference is made to the speaker, or, to put it in more general terms, to the user of a language, then we assign it to the field of pragmatics. If we abstract from the user of the language and analyze only the expressions and their designata, we are in the field of semantics. And if, finally, we abstract from the designata also and analyze only the relations between the expressions, we are in (logical) syntax. The whole science of language, consisting of the three parts mentioned, is called semiotic.

-Rudolf Carnap, 1942, [13(9)]

Syntactics₁: the study of the formal aspects of signs
[cf:55,56,57(13ff.),60(27ff.)].

Syntactics₂: the study of the relations of signs to other signs
[cf:56,57(7ff.),60(23ff.)].

Syntactics₃: the study of the way in which signs of various
classes are combined to form complex signs
[cf:57(14),60(28–29); cf:58(354–355),60(367)].

These three areas of research defined by the three characteri-
zations overlap but are not identical. In what follows we will therefore
use the term syntactics without a subscript only when we speak of
syntactics proper, that is the discipline whose subject matter is the
intersection of the subject matters of Syntactics₁ , Syntactics₂ and
Syntactics₃.

Formal aspects of signs

The question of what are the formal aspects of signs has been
given alternative answers by different traditions of semiotics. While
logic-oriented semioticians like Wittgenstein [94(§3.33)] Carnap
[11(1,208)], and Morris [57(13ff.),60(27ff.)] equate the distinction
between form and substance with the distinction between signs (B's)
and meanings(C's), linguistically-oriented semioticians like Saussure
[80(155–157)] and Hjelmslev [39(69–73, 98ff.),93(76–81,110ff.)] use
it to differentiate two kinds of aspects within signs (B's) as well as within
meanings (C's). Yet the underlying conceptions of form are quite
similar and are based on the theory of invariants as developed in
geometry in Klein's Erlangen Program [43(463–464)]. In configura-
tions of elements, two different types of entities may vary. On the one
hand certain properties of the configuration can change while others
remain constant, cf. movement in space under similarity transforma-
tion or mirroring where the location of a figure varies but all its spatial
proportions stay the same. On the other hand, the elements them-
selves can also change, as when geometrical figures are replaced by
sequences of letters or numbers. What remains invariant here is the
abstract structure of the figure; compare Holenstein [41(30ff.)] and
Wunderlich [95].

A generalization of geometry raises the following problem: Let there be a multiplicity of elements and a group of transformations defined on them; now the configurations of elements in that multiplicity should be studied with respect to those properties that remain unchanged when transformations of that group are applied to them [...]. The task is to develop the theory of invariants for that group.

-Felix Klein, 1872, [43]

The structure of a relation was extensionally defined by Russell
[79(59ff.)] and Carnap [10(13ff.)] as the class of relations isomorphic
with that relation. This approach was developed further in the
mathematical theory of structures published by the group of French
mathematicians Bourbaki [6]. It was applied to the theory of definition
by Hilbert, who proposed to define basic technical terms of a theory
implicitly by specifying the axioms in which they occur [37,38].

Carnap applied this idea to the study of language in general.
He was convinced that for every language one can work out *a formal
theory of the forms of that language* [11(1)]. It was the task of that
theory to specify the rules that determine the sign forms of a language.
For Carnap, the formal nature of the concrete individual sign was not
a problem, as it was for Hjelmslev (see below). Therefore he was
content to characterize the sign forms of a language by specifying *the
classes and serial relations* of their components [11(1)].

Analogous to Hilbert's program of metamathematics, Carnap's formal theory was to be formulated in a special metalanguage whose expressions refer to the object-language in question [12(5)]. Morris generalized this conception for sign systems of all kinds with all their aspects [cf:57(9), 60(23–24); cf:58(178–179), 60(256–257)]. If we call a sign system under study an object-code, Morris envisaged three different metalanguages dealing with three different dimensions of semioses involving signs in the object-code [57 (13ff., 21ff., 29ff.), 60(28ff., 35ff., 43ff.)]. These metalanguages differ in what their expressions refer to. While the pragmatic metalanguage refers to the interpreters and the semantic metalanguage refers to the meanings of the signs in the object-code, a metalanguage whose descriptive terms all refer only to the sign forms of the object-code is called a syntactic metalanguage. It is worth noting that each metalanguage itself has all properties of a sign system.

It is worth noting that each metalanguage has itself all properties of a sign system. Thus, the syntactic metalanguage not only has a syntactic dimension insofar as it contains signs of various classes with various serial relations holding among them, it also has a semantic dimension since its signs are interpreted to represent meaning and refer to something, namely, to the signs of the object-code; and it has a pragmatic dimension insofar as it can be used by special types of interpreters, namely, by syntacticians.

This being the case, it is the semantic dimension of the syntactic metalanguage that has to do with the syntactic dimension of the object-code. And it is the semantic metalanguage of the syntactic metalanguage that deals with the relations between signs of the syntactic metalanguage and the signs of the object-code. Viewed from this perspective, the text of this article can be understood to be written in the pragmatic metalanguage of the syntactic metalanguages devised by semioticians of various traditions to deal with object-codes.

What has been said about the syntactic metalanguage so far takes care of the terms forms of a language in Carnap's program and *formal aspects of signs* in Morris' version thereof. Understood in this way, Syntactics$_1$ becomes a subdiscipline of Syntactics$_2$. There are, however, two problems left; one is the task of setting up a formal theory within the syntactic metalanguage (see below, p. 44–45).. The other is the problem of characterizing the formal aspects of a sign that is not a complex sign. The latter problem was approached by Hjelmslev, who, like Carnap [10(11)], insisted *that a totality does not consist of things but of relationships* [39(22),93(23)]. This approach had been successful in the theory of human speech sounds.

Reflecting on Trubeckoj's analysis of vowel systems [87], Bühler had distinguished the acoustic sign from the concrete sound event by saying that the former was connected with the latter as form is connected with unformed matter [7]. In 1934, Bühler described the complex relation between the properties of sign matter and sign form with reference to the areas of two overlapping geometrical figures [88(28,42 ff.)]: In order to recognize the sign form in the sign matter produced in semiosis, the interpreter must, on the one hand, concentrate on the relevant properties of the sign matter and abstract from the irrelevant ones, the principle of abstractive relevance; and, on the other hand, complement properties of the sign form not manifested in the sign matter, the principle of apperceptive complementation of the sign gestalt. The distinction between sign matter and sign form can be exemplified by the way different languages pattern the sign matter which Berliners produce in order to name their city.

In intuitive number theory formulas were always exclusively used for communication. The letters stood for numbers and an equation communicated the fact that the two numbers coincided. In algebra, on the other hand, we regard expressions containing letters as independent structures which formalize the material theorems of number theory. In place of statements about numbers, we have formulas which are themselves the concrete objects of intuitive study. In place of number-theoretical material proof we have the derivation of a formula from another formula according to determinate rules.
- David Hilbert, 1925
[38 (174–175), 73 (145)]]

... a totality does not consist of things but of relationships, and ... not substance but only its internal and external relationships have scientific existence ...
- Luis Hjelmslev, 1943, [39, 93]

Hjelmslev, who uses this example, describes it by saying that one and the same sign matter—purport—is modeled into different sign substance through the sign forms supplied by the different languages [39(53),93(56)]. The sign forms comprise the language-specific invariants patterning sign matter. According to Hjelmslev, these invariants are independent of the medium involved; thus a given sign form can be realized by sign matter in various media, as when the speech chain of German [bɛr'liːn] is transformed into the written word Berlin. From this he concludes that "Substance" cannot itself be a *definiens for a language* [39 (91–92), 93 (103–104)].

English: [bɘ :'l I n]

German: [b ɛ r 'l i : n]

Danish: [bæ ɹ 'l i ʔ n]

Japanese: [b ɛ λ u λ i n u]

Figure 2. Signs for Berlin

What is true for language also holds for all other sign systems. In phonology, the difference between substance and form is captured terminologically by the distinction between phonetic and phomenic entities, studied by phonetics and phonemics, respectively. This distinction was generalized in American structuralism by isolating the suffixes -etic and -emic and using them in the description of nonlinguistic sign systems [4,68]. A description in terms of behavioremes considers all and only those properties of a given behavior that are relevant for it to represent meaning to interpreters of the kind in question, while a description including other aspects of behavior would be called behavioretic. In summary, it should be noted that syntactics studies sign forms and disregards sign substance and sign matter; it includes phonemics and excludes phonetics.

This delimitation, which relies on the differences between concrete and abstract, should not be confused with a distinction introduced by Peirce, and developed further by Reichenbach, which is based on the difference between individual and general [65(§4.537),75(4,21,284,336)]. For practical purposes, sign forms must be reproducible since we want to use them on more than one occasion. The individual sign form is called a token. Thus, the two sentences *Whatever happens, Berlin will remain Berlin* and *Berlin is situated in Germany* contain the same word *Berlin*, but appearing in three different tokens; and in giving the explanation, a fourth token of the word has been produced. This can be described by stating that the four sign forms are tokens of the same sign type. The common formulation "the same sign occurs in different places" amounts to saying *(sign (form))* tokens of the same *(sign (form))* type occur in different places. The independence of the type/token-distinction from the form/substance/matter-distinction is demonstrated by the fact that one can distinguish tokens from types in sign substance as well as in sign matter.

If child is the topic of the message, the speaker selects one among the extant more or less similar nouns like child, kid, youngster, tot, all of them equivalent in a certain respect, and then, to comment on this topic, he may select one of the semantically cognate verbs sleeps, dozes, nods, naps. Both chosen words combine in the speech chain.

- Roman Jakobson, 1960, [42]

Relations between signs

The statement that a complex sign form like *Berlin will remain Berlin* contains two component sign forms that are tokens of the same type is a statement about a relation between these sign forms and thus falls into Syntactics$_2$, the study of the relations between signs. Traditionally, there are said to be two kinds of relations between signs [57(6–7,18ff.), 60(21–22,32ff.)]:

• relations between signs occurring in a given complex sign

• relations between signs in a sign system or code.

Relations of the first kind are usually exemplified by syntagmatic relations, relations of the second kind by paradigmatic relations, as described by Kruszewski [45], Saussure [80], and Hjelmslev [39]. The difference can best be demonstrated with respect to the process of sign production. In producing a complex sign, the sender will make successive selections from the inventory of a sign system mastered by him and combine, according to certain rules, the chosen elements into an appropriate structure. Jakobson considers natural languages like English to be sign systems, and sentences like the child sleeps as results of sign production [42(358)]. The set of elements that provides the basis of selection in each step of the sign production is called a *paradigm*, and the result of the combination of the elements selected is called a *syntagm*.

"Substance" cannot itself be a definiens for a language [...]. Here is a graphic "substance" which is addressed exclusively to the eye and which need not be transposed into a phonetic substance in order to be grasped or understood.
- Luis Hjelmslev, 1943
[39 (91–92), 93 (103–104)]

Paradigms need not consist of semantically equivalent signs as in Jakobson's example, but they can consist of signs having the same distribution in syntax like sleeps, lies, stands, or of signs belonging to the same lexeme like sleep, sleeping, sleeps, slept, or of signs containing the same root like sleep, sleeper, sleepy, or of signs having the same phonemes in certain positions like sleep, sweep, steep, or even of signs having the same subphonemic properties like German ich, nicht, Licht, where χ is pronounced differently from ach, Nacht, lacht.

Semantic, syntactic, inflectional, derivational, phonemic, and phonetic paradigms all have the same structure: Each of them is a class of elements equivalent to one another in a certain respect. Paradigms that fulfill additional conditions, such as that of mutual substitutability of all their elements in specified types of context *salva bene formatione* (i.e. with preservation of well-formedness), are called syntactic categories [2].

While paradigms are constituted by relations of (partial) equivalence, syntagms are constituted by relations of contiguity. Contiguity can be conceived of as neighborhood in space or time, as a restriction determining the distribution of one constituent with respect to another, or as a dependency relation like agreement in number between a and child or agreement in person and number between child and sleeps in Jakobson's example. Since syntagms are complex signs produced by some interpreter, syntagmatic relations are part of the surface structure of those signs. A syntagmatic relation is to be distinguished from a deep-structure relation and from a syntactic rule determining either of them [70(129–159)].

Although originally defined by Saussure [80(171)] and by Carnap [11(1)] as a term for linear configurations, or serial relations of signs (i.e., text), the term *syntagmatic relation* is also applied to signs combined in more than one dimension as occurring in visual art, music, theatre, and film.

Syntagmatic and paradigmatic relations are conceptually distinct, but they can occur together as in paradigms of syntagms: The child sleeps, The youngster dozes, The kid nods, The tot naps constitute a pardigm of elements equivalent with respect to the syntagmatic relations holding within each of them; another case in point is the inflectional paradigm exemplified above.

The disciplines studying paradigmatic and syntagmatic relations between signs are called paradigmatics and syntagmatics, respectively. They are part of Syntactics$_2$.

Syntactics must not be confused with syntagmatics and with syntax as defined in linguistics. As is obvious from the examples discussed, paradigmatic and syntagmatic relations can be found on all levels of language. This fact has been exploited by structural linguists, such as Bloomfield [4], Harris [32], and Hjelmslev [39], to use these relations in the definition of the levels of language and of the disciplines studying them: phonetics studies the physical properties of linguistic sound matter; phonemics studies the relations between phonemes, that is, the smallest sound forms used to distinguish the signs of a language; morphology studies the relations between morphemes, that is, the smallest combinations of phonemes representing meaning to the language user, and their combinations into words (derivational morphology), and word forms (inflectional morphology); syntax studies the relations between phrases, that is, combinations of word forms within and into sentences; lexicology studies the relations between paradigms of word forms having the same meaning. Of these disciplines, phonetics does not deal with formal aspects of signs and is therefore excluded from Syntactics$_1$; phonemics deals with formal aspects of signs, but not with combinations of signs and is therefore excluded from Syntactics$_3$; inflectional and derivational morphology and syntax deal with formal aspects of signs, their relations, and their combinations and are part of syntactics proper; lexicology deals with formal aspects of signs but not with their combinations and is therefore excluded from Syntactics$_3$..

As it turns out, syntactics proper includes only morphology and syntax from the linguistic disciplines and it is no accident that this is exactly what linguists have traditionally called grammar. Thus it is justified to regard syntactics as a semiotic generalization of grammar.

In many contexts, the Carnapian identification of syntactics with syntax is highly misleading. Only in sign systems which do not require a distinction between morphology and syntax is it unproblematic to equate syntactics with syntax. This is the case in sign systems such as the numerals and in most of the formal languages so far constructed in logic.

Syntactics proper contains both syntagmatics and syntax as subdisciplines, but syntagmatics overlaps with syntax, since syntax studies not only syntagmatic but also paradigmatic relations between phrases and syntagmatics studies not only phrases but also morphemes and phonemes.

Analysis and synthesis of complex signs

In his program for a *logical syntax of language*, Carnap had envisioned "a formal theory of the forms of a language" to be formulated in a syntactic metalanguage [11(1)]. There have been various attempts to work out such a formal theory. Most of them have been guided by the idea of a calculus, that is an axiomatic system that has the properties of an algorithm for specifying exactly the set of all signs belonging to the object-code under investigation.

The specification of a set of more or less complex objects can be given either by starting with the complex objects and introducing rules for their analysis into componets, components of components, etc. until elementary objects are reached. Or one can proceed from elementary objects and introduce rules for their use in the synthesis of more and more complex signs. The two approaches are of different value for different kinds of sign systems.

For many sign systems that are in use in human or animal societies or within organisms or machines, it is by no means clear what the basic elements are. The most controversial examples include dance, gestures, pictures, films, and architecture. However, there are also sign systems where it is clear what the elementary signs are and hard to decide for a given complex sign whether it is part of the sign system in question or not and what is its structure. Such cases occur in some of the richer artificial languages of logic and mathematics. For these reasons it has become customary to use the analytical approach in the study of natural sign systems that have historically grown and the synthetical approach in the study of artificial sign systems; in this context, Lotman [49,50] distinguishes between text-oriented and grammar-oriented cultures, and Eco [23(137ff.] and Pape [62] scrutinize this distinction.

Linguists such as Bloomfield [3,4], Harris [32], Wells [91], Pike [68], Hockett [40], Hjelmslev [39], and Prieto [72] have developed procedures for the step-by-step analysis of texts into components, components of components, etc. The formal theory for this approach has been discussed by authors such as Hjelmslev [39], Marcus [51], and Harris [33]. According to Hjelmslev, syntactic theory has to provide a general calculus containing rules of partition for complex signs in all sign systems. The application of such a calculus to a given complex sign involves a finite set of partition operations, the last of which will yield basic elements of the sign system in question. The syntactic structure of that complex sign is described by describing its analysis. The basic elements of the whole sign system are obtained by analyzing complex signs belonging to the system until no new basic elements are generated [39(27–31),93(28–33)].

In judging the value of this approach one must distinguish between the continental European tradition and the American tradition. The first relies on Hjelmslev's commutation method, which is applicable to sign systems of all kinds, but does not abstract from the meaning of the signs analyzed, in the way required by Carnap and Morris. The second abstracts from the meaning of the signs analyzed, but relies on the method of parsing, which is only applicable to languages.

Philosophers and logicians such as Leibniz [44], Boole [5], Frege [25,26], Schroeder [82], Peano [63], Peirce [66], Whitehead and Russell [92], Carnap [11,12,14] and Curry [21] were the first to develop step-by-step procedures for the construction of more and more complex signs out of basic elements. The formal theory for this approach has been given by authors such as Thue [85], Post [71], Turing [88,89], Hermes [35,36], Markov [85], Lorenzen [48], Davis [22], Trakhtenbrot [86], Chomsky and Miller [19], Bar Hillel [2], Lindenmayer and Rozenberg [46,47] Rozenberg and Salomaa [78].

According to Chomsky, syntactic theory has to specify the general form of a calculus that generates all the expressions, that is, the simple and complex signs, of a given language, starting from a finite set of basic elements and using a finite set of rules of various types. The application of such a calculus to an initial string involves a finite set of production operations, the last of which yields an expression of the language in question. The syntactic structure of that expression is described by describing its production. The set of expressions of the language is obtained by applying the rules of the calculus to all its basic elements [16(18–91)].

Compared with the analytic approach, the calculi developed for the synthetic approach have reached a much higher sophistication. In addition, logicians like Carnap [11(8)], Quine [74], Montague [53,54], and Cresswell [20] and linguists like Chomsky [17] and Shaumyan [84] have shown that it is possible to apply the synthetic approach in the analysis of natural languages also by using the so-called *indirect method* as discussed by Schnelle [81]. The point of this method is to introduce an artificial sign system in the metalanguage, which can be kept under tight control by means of the stipulative definition with which it was constructed, to compare this sign system with the object-code, and to incorporate more and more features of the object-code in it so that in the end the set of signs belonging to the object-code becomes completely reconstructed in the metalanguage.

This strategy has worked well in the analysis of natural languages. If it is to be applied to the study of nonlinguistic sign systems, an additional obstacle has to be overcome. In language, the relations between the components of a complex sign are generally thought to be based on one single serial relation, for example the relation *following in time* as in speech or *immediately to the right* as in European writing systems. Complex signs governed by serial relations can be produced through application of an associative noncommutative binary operation called concatenation. However, as shown above, there are sign systems that have either additional serial relations or equivalence relations or relations of more complex types governing their complex signs.

If one wants to describe the syntactic structure of complex signs in sign systems using operations different from concatenation, one can again choose either a direct or an indirect strategy. The first strategy consists in defining appropriate operations of combination and describing the complex signs directly on their basis. This strategy is applied in the logic of relations by Peirce [64,66,67] and Roberts [76] and discussed in computer graphics by Faiman and Nievergelt [24], Rosendahl [77], Gips [28], and Gonzalez and Thomason [29].

In the second strategy, a system of notation is devised to represent the relevant features of the complex signs in question in a way that makes them more amenable to linguistics-type syntactic analysis. Notational systems tend to reduce multidimensional sign configurations to two-dimensional ones, scores, or one-dimensional ones, strings. Examples are musical notations and the phonetic transcriptions of natural languages. Theoretically, it is always possible to reduce a given n-dimensional sign complex to a complex with n-1 dimensions as long as the relations among its constituents are serial or equivalence relations as argued by Greenberg [32 (95–96], Curry [21 (50–69)], Goodman [30 (127–224)], and Fu [27].

Conclusion

It is possible to describe the syntactic structure of sign systems which fulfill two conditions:

- A set of basic elements is given from which all well-formed signs of the system can be constructed by combinatory operations.

- All combinatory operations can be reduced to or defined on the basis of one single binary operation, namely, concatenation. All complex signs of the system therefore are, or are reducible to, strings.

Sign systems with these properties are called string codes. They include, among others, natural languages, writing systems, musical notations, vestimentary codes, culinary codes, and traffic signs.

As a technical device for the syntactic description of string codes, formal grammars have been developed which may be characterized as string production grammars. They are a special type of the so-called generative grammars described by Chomsky [16, 18], Bar Hillel [2], Marcus [51], and Hermanns [34]. Formal definitions for the concepts of a string and a string code, as well as basic types of string production grammars, and explications of the concepts of their syntactic structure and structural description are presented in the author's original article, *Syntactics* [83].

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Glossary

CODE: System of entities that can be interpreted by someone as representing something, i.e, sign system.

COMPLEX SIGN: Sign consisting of other signs.

CONCATENATION: The act or state of being linked together.

CONNECTIVE: A linguistic form or logical symbol which is used to connect words and expressions

CONTIGUITY: Neighborhood in space or time.

GRAMMAR: Morphology and syntax.

INTERPRETER: Who interprets something as representing something in semiosis.

LEXICOLOGY: The study of the relations between paradigms of word forms having the same meaning.

MEANING: What is represented by signs for interpreters in semiosis.

METACODE: System of signs that represent the signs of another code (the object code).

METALANGUAGE: Metacode which consists of linguistic signs.

METAMATHEMATICS: The study of the way mathematics studies its subject matter.

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MONOID: A singular atomic entity.

MORPHEMES: The smallest combinations of phonemes representing meaning to the language user, and their combinations into words and word forms.

MORPHOLOGY: The study of relations between morphemes.

PARADIGM: Set of elements that provides the basis of selection in each step of sign production.

PARADIGMATIC: Relating to clear models and archetypical examples.

PARADIGMATICS: The study of paradigmatic relations between signs.

PHONEMES:The smallest sound forms used to distinguish the signs of a language.

PHONEMIC: Relating to the characteristics of phonemes.

PHONEMICS: The study of the relations between phonemes.

PHONETIC: Relating to the system of speech sounds for a given language.

PHONETICS: The study of the physical properties of linguistic sound matter.

PHONOLOGY: Phonetics and phonemics.

PRAGMATICS: The study of the conditions an entity must fulfill to be able to interpret signs as representing meaning in semiosis.

SEMANTICS:The study of the conditions an entity must fulfill so that can be represented by signs for interpreters in semiosis.

SEMIOSIS: The process in which something functions as a sign, that ia a process in which some A, interprets some B as representing C.

SEMIOTICS: The study of semiosis.

SIGNIFICATION: The process of conveying meaning through symbolic means.

SIGN FORM: Code-specific invariants that allow to recognize a given sign matter as token of the same sign.

SIGN MATTER: Physical manifestation of a sign form.

SIGN SUBSTANCE: Sign matter patterned by a sign form

SIGN TOKEN: Individual sign form.

SYNTACTICS: That branch of semiotics which studies the formal aspects of signs, the relations between signs, and the combinations of signs.

SYNTAGM: Result of combining elements in the course of sign production.

SYNTAGMATIC: Relating to a specific syntactical element.

SYNTAGMATICS: The study of syntagmatic relations between signs.

SYNTAX: The study of the relations between phrases, i.e., combinations of word forms within and into sentences.

TOKEN: A symbol taken to be an instance of a linguistic expression.

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Languages of design

Formalisms for Word, Image, and Sound