A Peircean Ontology of Semantics

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Abstract. Peirce's semiotics can be effectively used for modeling different sorts of signs. In this paper it is argued that semantic signs, which are signs from the semantic point of view, are no exception. It turns out, however, that a proper modeling of semantic signs needs a better understanding of the concept of qualisigns, as well as, of the relation between Peirce's categories and his theory of signs.

1 Introduction

Recently we introduced a cognitively based model for Peirce's semiotics and its application to Boolean logical ([4]), morphological and syntactical ([8]), and syllogistic logical signs ([9]). The purpose of this paper is an attempt to use our theory to semantic signs as well. We will argue that the cognition of such signs amounts to a process which, by merging sensory and memory input qualities, represents the observed phenomenon as a proposition. In this paper, we will refer by *semantics* to such a cognitive process. It will be argued that the perception of a phenomenon involves the generation of semantic signs signifying the relation between external (sensory) and internal (memory) information. Such a process is Peircean in spirit: although our perception of the 'real' world phenomena arises from our thoughts, which are *facts* ([12]), only those thoughts will appear in our conception which are forced by the *hard* reality ([1]). A related problem discussed by Peirce is *perceptual judgment* ([7]5.15).

What makes Peirce's framework especially attractive, is the fact that it allows for a *single* approach which can be uniformly applied for modeling the external input and internal knowledge, as well as, their relation. The purpose of this paper is an attempt to give a Peircean account of this last aspect of relation. An essential constituent of the above approach is Peirce's classification of signs ([7]2.243) which consists of nine kinds of aspects, or signs, that can be distinguished in the 'real' world. Another component is the concept of a sign interaction ([3]) which reveals how signs can emerge from other signs. Notice that sign interactions are a consequence of the inherently *dynamic* character of Peirce's definition of a sign.

The semantic model presented in this paper can be said to be a preamble of the other models of signs mentioned above. That our earlier and current results are compatible, indicates the robustness of our cognitive interpretation of Peirce's semiotics. The late introduction of a Peircean model for semantics can be justified by the fact that semantic rules are typically more complex than, for example, the rules of syntax.

2 The cognitive model of signs

In this section we recapitulate the basics of our cognitive model of signs ([3]). Following cognition theory ([6]), the recognition of any sign begins with the sensation of the physical input which is processed by the brain in percepts. The generation of a percept is typically triggered by a change in the input. By comparing the current percept with the previous one, the brain can distinguish between two sorts of input qualities: one, which was there and remained there, which is called a *continuant*; and another, which was not there, but is there now (or vice versa), which is called an *occurrent*. The collections of continuants and occurrents, which are inherently related to each other, form the basis for our perception of a phenomenon as a sign. By means of *selective attention*, the qualities of these collections are further classified in two types: *observed* and *complementary*.

We will refer to these qualities collectively as the *input*. We will assume that the (sets of) qualities *are* the elementary signs we observe: qualities which are signs. Such signs are called by Peirce a *qualisign*. Qualisigns are special signs for which we have no denotation (except, on the level of description).

Any sign is situated in the context of other signs which may affect the sign's meaning. In this regard we assume that the input may also contain qualities from the memory. The hidden agenda of this paper is an attempt to find an explanation for such embedding in terms of the sensory and memory qualities.

According to Peirce, every sign can be analyzed as the *triadic relation* between the sign itself, its object, and its interpretant. The irreducible character of this trichotomy implies that any reference to a sign is doomed to be ambiguous. This ambiguity may be considered the price to be paid for having an inherently dynamic concept as a basis. Peirce also defined an ingenious classification of signs consisting of nine kinds of sign which may be arranged in a matrix (see fig. 1). In what follows, we will refer to this representation as the *sign-matrix*.

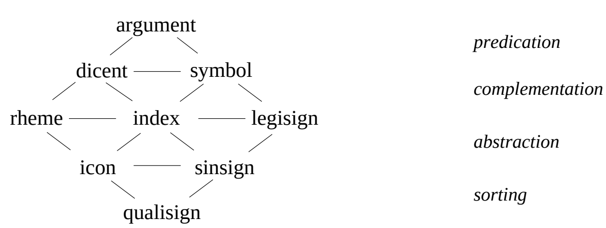

Fig. 1. The sign-matrix

As we mentioned, Peirce's classification of signs can be identified in different symbol phenomena like Boolean logic, syntax etc. We will capitalize on this isomorphism and alternatively refer to a sign by means of the corresponding Boolean logical expression. The classification of such expressions is displayed in fig. 2. When it is clear from the context, a sign class and its element may be uniformly referred to. For example, the reference to a rheme may denote (context dependently) a single rheme sign, or the rheme class of signs itself.

In [4] we argued that semiosis can be defined as a process in which triadic relations arise recursively, revealing gradually more accurate signs of the observed phenomenon. Our research has pointed out that a proposition sign of the input can be defined to arise from the qualisigns (which are qualities) via the *interaction* of adjacent signs (such signs are connected in fig. 1 by a horizontal line). An icon and sinsign emerge from the qualisigns by *sorting* which is a degenerate form of an interaction. A rheme, index and legisign arise by *abstraction*, via the interaction of an icon and a sinsign. A dicent and symbol sign are yielded by *complementation*, respectively, via a rheme–index and an index–legisign interaction. Finally, an argument sign is generated by *predication*, via the interaction of a dicent and symbol sign. With respect to the definition of signs and the various stages of sign recognition we refer to [8].

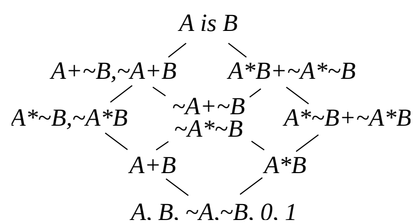

Fig. 2. The classification of Boolean signs

2.1 An alternative definition of logical signs

For a proper characterization of the classes of semantic signs we will need an alternative formulation of the logical expressions of some of the Boolean signs. An alternative definition of the qualisign is postponed to section 4. The logical representation of the icon ($A+B$) and sinsign ($A*B$) which, respectively, denote the listing of the qualities of a phenomenon and the occurrence of those qualities as a single event, are unchanged.

The logical expressions of the rheme can be re-formulated as $(A+B)*\neg A$ and $(A+B)*\neg B$, in which form, the meaning of the rheme can be explicated as a relation between the icon sign of the input ($A+B$) and the individual complementary signs ($\neg A$, $\neg B$). By virtue of the duality of signification (which aspect will be discussed in section 3), the occurrent qualities of $\neg B$ can only be combined with the continuant ones of A. An example of such a completion is the following. Consider the perception of a running rabbit, and assume that the continuant qualities observed amount to the sign of the rabbit's silhouette. Using this sign and our knowledge about rabbits, which is a complementary sign with respect to the actual observation, we can reveal the possible properties of the observed rabbit, for example, that its color can be grayish and that it can have long ears.

The alternative formulation of the legisign is $(A{+}B){*}(\neg A{+}\neg B)$. Following this expression, the legisign is signifying the input via the relation of the signs of the observed and complementary phenomena, as an abstract event.

The index, represented by the expressions $\neg A{+}\neg B$ and $\neg A{*}\neg B$, refers to the context of the actual observation. The resemblance of these expressions with those of the icon and sinsign must be clear. Accordingly, the index can be said to signify the complementary context of the observation as a 'real' phenomenon. But the index has also another meaning which is due to the DeMorgan postulates. These rules are expressive of the relation between the observed and complementary phenomena as a sign, or alternatively, of the semiotic concept of *negation*. Notice that the DeMorgan rules are applied, although implicitly, in the generation of every Boolean sign that involves the combination of observed and complementary qualities (except for the qualisign, icon and sinsign, all signs appearing in fig. 2 have that property).

The logical representation of the dicent is $A{+}\neg B{=}A{\leftarrow}B$ and $\neg A{+}B{=}A{\rightarrow}B$. The dicent sign refers, via the logical dependency between A and B, to the different *views* of the subject of the observation. These views belong to each other, in some sense. The alternative form of the symbol, $(A{+}\neg B){*}(\neg A{+}B)$, emphasizes precisely this last aspect. In the symbol sign, the two views of the dicent are *contrasted* (which is a form of completion) and their relation is defined as a characteristic property.

Finally, the argument sign is alternatively formulated as $A(\neg A)$ *is* $B(\neg B)$, in which form the argument is signifying the input phenomenon as the relation of the observed qualities embedded in the context of the complementary ones.

3 Natural duality

The ground for any sign is a contrast in the 'real' world. The potential existence of a contrast is however not sufficient for having a sign. From Peirce's definition it follows that a sign will only function as a sign, if it is interpreted as such.

In our model, signs arise from the perception of the physical stimulus which is a firstness category phenomenon ([7]1.302). Such a phenomenon is represented by the collections of continuant and occurrent qualities which define a contrast. In this paper we will argue that such a contrast is a consequence of the presentation of 'real' world phenomena as a *dual* modulation of some carrier.

A dual modulation is a pair of interrelated properties of a carrier characterizing a phenomenon. For example, a wave phenomenon (e.g. light) is completely characterized by the frequency and intensity of the carrier (e.g. a photon stream). An overview of the types of phenomena, their carriers and modulations is displayed in fig. 3. The source of the carrier and the modulation are independent from each other. The carrier is 'used' by the modulation as a vehicle for representing a phenomenon (cf. fig. 4). For example, in the case of a light phenomenon, the source of the carrier can be the sun, the carrier itself the light beams, and

types of phenomena	**carrier**	**modulation**
wave type	continuous stream	frequency/amplitude
mechanical	energy	distribution/intensity
chemical	chemical bond	consistence/solubility
(sign)	(information)	(form/content)

Fig. 3. Duality of natural phenomena

the modulation can be due to a light reflecting object. The properties constituting a modulation are incomparable, and only the *interaction* of such properties (which involves the aspect of a contrast) can represent a phenomenon. The *interpretation* of such an interaction (for example, by nature itself) is what we call the presentation of a phenomenon, or briefly, a phenomenon.

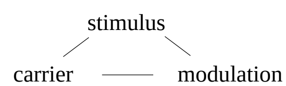

Fig. 4. The signification of physical phenomena

Because the process of sign recognition is a phenomenon, we argue that the contrast between continuant and occurrent, as well as, the concept of a sign interaction follow directly from the duality of natural phenomena. The continuant and occurrent collections define a dual modulation of the carrier, which is information. Hence, our model of Peirce's semiotics may be said to justify his hypothesis, according to which, human cognition must have a foundation in 'real' world phenomena.

4 Qualisign revisited

The representation of the sensory input as a dual modulation of continuant and occurrent qualities is the first step towards the full recognition of the input. In this section we will focus on the question how such sensory qualities can be combined with memory qualities into a single sign. Briefly, our answer will be that the sensory input is triggering the memory, which in turn provides a response, and that the *combination* of the two sources of input will be represented as a sign, which is a qualisign.

4.1 Memory signs

Memory signs are no different from other signs. Hence, also a memory sign can be modeled as a pair of collections of qualities. Because qualisigns are independent signs, we may assume that the input qualities are triggering the memory type-wise. This means that the collections of a memory sign are individually referred to. Such an individual collection will be called a continuant or occurrent memory sign.

A continuant memory sign is modeled as a reference to a discrete value, which is the denotation of some 'thing'. An occurrent memory sign is represented by a reference to a dense interval. We assume that there exists a monotonous function mapping such an interval to a linearly ordered set of discrete values which is called a 'scale'. When an occurrent memory sign is triggered by the input, the response will be represented by a point of an interval. The location of such a point is determined by the zero point of the interval (which is defined by the sensor's threshold value) and, by the difference between the previous and current values of the occurrent input qualities which is a *relative* value.

An advantage of this representation of memory signs is that it can explain the exceptional flexibility of signification. Because different observations can yield the same relative value, memory signs can be efficiently re-used. For example, a given point of the memory sign "velocity", denoted by the scale value "fast", can equivalently represent the observed motion of a race car, or of a rabbit, in spite of the obvious differences between the absolute values of their speed.

4.2 Semantic qualisigns

The above analysis of signs emerging from firstness category phenomena will be the basis for a more refined definition of the concept of a qualisign, which will be called a *semantic* qualisign. We argue that such a definition requires the introduction of a classification for qualisigns. Accordingly, in this section we will refer by a type of sign to such a classification. Another example for a nested classification of signs can be found in our model of syntactical and morphological symbols ([8]).

The novel element of semantic qualisigns is due to the refined definition of the input as a *combination* of sensory and memory qualities. Following our earlier model of signs, the input qualities can be classified in four collections which amount to the qualisigns of the nested classification to be defined. Remember that those collections refer to the main divisions of continuant and occurrent, and the subdivisions of observed and complementary qualities. In what follows, we will refer to these collections as a, a', b and b'. We will assume that the two sources of input are distributed over these collections as follows: the observed collections, a and b, contain sensory qualities; the complementary ones, a' and b', consist of memory qualities.

Since qualisigns are independent signs, we may restrict ourselves to the definition of one type of them. Accordingly, we will only define the generation of the continuant qualisigns, A and $\neg A$, from the collections a and a'. In what follows, we will refer by a memory sign to a continuant memory sign. A classification of continuant qualisigns can be given analogously to Boolean logical signs. The result of this is displayed in fig. 5, the trivial details of the process of sign generation are omitted. However, a few comments may be in place here. Because the whole of the sensory qualities (a) is related to the whole of the memory response (a'), there will not be negated signs. The qualities of a and a' will be modeled, respectively, as some 'thing' and some 'property'. Remember that in the representation of the rheme and legisign, the "$*$" relation is expressive of the meaning of completion.

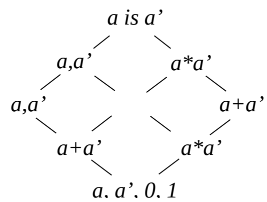

Fig. 5. The classification of continuant qualisigns

Although the classification of fig. 5 seems not very helpful, we will see that it can be profitably used for the refinement of the meaning of the argument sign, a *is* a'. Notice that, by virtue of the nested character of this classification, such an argument sign will be a qualisign in a subsequent (higher level) sign generation. The basic idea behind the refinement of a *is* a' follows from the specific interpretation that can be assigned to memory signs. Conform with its meaning, a memory quality (a') can either refer to a 'valid', or a 'not valid' relation with a sensory quality (a). This can be explained as follows.

Triggered by the sensory input (a) the memory generates a response, which is a set of qualities. Qualities having an intensity above a given threshold characterize a *valid* relation of a and a', the remaining qualities of the response represent a *not-valid* one. Although a and a' are related also in such a case, their relation does not primarily characterize the actual observation. Let us mention that, on the basis of the memory qualities corresponding to the two parts of a', a fuzzy logic can be defined. The size of the set of memory qualities referring to a valid relation divided by the size of the response set as a whole can be used to define the value of a corresponding probability variable.

The relation between a and a', whether valid or not, is always based on *similarity* which involves the existence of a common reference and a shared object. Recent research in cognition theory has pointed out that similarity may be the primary means of representation of perception ([5]). In this paper it will be argued that similarity has two interpretations which are 'orthogonal' (cf. duality): a formal (topological), and a temporal one. These interpretations can be easily recognized in the meanings of the "$+$" and "$*$" relations representing logical signs, for example, in the expressions of the icon and sinsign.

Analogously, in our definition of the qualisigns we will assume that sign generation is based on a *single* operation, but which has two different interpretations. Therefore, conform with the two meanings of a', we will distinguish between two kinds of argument signs. Because signs are *unique*, we have to introduce different representations for them. By examining the classification of fig. 5 we may observe that an argument sign which refers to a valid relation between a and a'

can be represented as $a{*}a'$. Indeed, by virtue of its aspect of simultaneity, the "$*$" relation can properly express the interrelatedness of a and a'. Analogously, the sign of a not-valid relation can be signified by the expression $a{+}a'$. Such a relation refers to a phenomenon, the parts of which are separately observable and have an individual meaning. This interpretation is conform with the logical meaning of $a{+}a'$ consisting of a, a', and both a and a' (in short, aa'). Notice that aa' is only expressive of the common reference of a and a', but it does not contain the aspect of an event. Hence, in $a{+}a'$ the qualities of a and a' must be complementary. This interpretation of $a{+}a'$ amounts to the semiotic definition of negation relative to the qualisigns.

In sum, the refined definition of the argument signs of the nested classification which are the semantic qualisigns of a subsequent sign generation, can be given as follows: $A{=}a{*}a'$, $\neg A{=}a{+}a'$, $B{=}b{*}b'$, $\neg B{=}b{+}b'$ (1 and 0, respectively, denote the presence and absence of input).

The qualisigns of the nested classification can be characterized as a dual modulation of information. Accordingly, the collections a, a', b and b' can be said to denote, respectively, "energy", "function", "reason" and "effect" (the last two refer to the possible causation of the observed phenomenon).

5 Semantic signs

We will introduce semantic signs on the basis of the above specification of qualisigns. Earlier we mentioned that any sign, also including semantic signs, emerges from the perception of the physical stimulus. Due to our cognition potential and memory knowledge we are able to recognize such a firstness category phenomenon as a qualisign, and eventually, as an argument sign containing the full meaning of the actual observation which, as any sign, is a thirdness category phenomenon. Remember that, except for the argument sign, the signs generated during this process are not recognized isolatedly and, therefore, can be considered degenerate signs ([8]).

We argue that in the process of semantic sign recognition memory knowledge is applied in stages. These stages correspond to the levels of the sign-matrix (cf. fig. 1), as well as, to Peirce's categories, firstness, secondness and thirdness. This relationship can be explained as follows.

Peirce's categories are related to each other according to a relation of *subservience*. The paradox of this relationship is that, though thirdness is more complex than either secondness or firstness, it nevertheless *needs* the relatively lesser significance of secondness and firstness ([1]). We argue that the ordering of the levels of the sign-matrix and the induced ordering of the subservience relation of the categories are isomorphic. Accordingly, a sign generated on some level will be said to signify a phenomenon of the category of the same level. From this it follows that the full recognition of the input amounts to the generation of signs signifying phenomena of increasing complexity.

Semantic sign generation is based on the same idea. We argue that on each level of the sign-matrix only those qualities of a semantic sign are 'functional' (if there are any) which can contribute, via sign interaction, to the generation of a sign signifying a phenomenon of the corresponding category. Briefly, the generation of the icon and sinsign corresponds to the first approximation of the sign of the observation. The interaction of the icon and sinsign yields the meaning of a firstness category phenomenon, the sign of which is a rheme, index and legisign. The interaction of these signs generates the sign of a secondness category phenomenon, and this process goes recursively further until an argument sign is generated. The potential of a memory quality for the signification of a phenomenon of some category will be called its *category aspect*.

According to our model of signs, the generation of a proposition of the observed phenomenon is the final goal of cognition. If, for example, the input refers to a firstness category phenomenon, its meaning will be recognized as a sign via the interaction of the icon and sinsign. In such a case, the remaining higher level sign interactions will not add anything to its meaning, except from the point of view of the process of sign recognition itself. From this understanding of sign generation we may conclude that the *binding* factor between Peirce's theory of categories and his semiotics is his concept of interpretation.

According to Peirce, the most complete signs are the icon, index and symbol. We argue that in the process of sign generation precisely these signs are the decisive constituents. By this we mean that the qualities of *these* signs are the dominant factor in the determination of the information mediated by a sign interaction and that such information is *limited* by the category aspect of these signs ([10]).

Let us finally mention that, in our model, the appearing first signs are the icon and the sinsign, from which the icon is the more complete sign. From this it follows that we always perceive a 'real' world phenomenon as an 'event' which is basically signified by some 'thing' (remember that the icon is the listing of the parts of a phenomenon). The above conclusion is reinforced by the fact that also the index and symbol signs contain the meaning of the icon, although only degenerately ([7]2.248).

5.1 Example

We consider the observation of the sample phenomenon of an escaping rabbit depicted in fig. 6. Our rabbit is running, perhaps because it is being chased by a fox, but this information is not part of our input.

The category aspect of a memory quality will be given by an integer (1,2 or 3) enclosed in parentheses. Because the category aspect of a sensory quality is always firstness, its specification will be omitted. Conform with the subservience relation of categories, it will be assumed that the denotation of any of the less significant meanings of a memory sign can be derived. For example, the meaning of 'escaping'(3) contains the meaning of a 'kind of'(2) 'running'(1) event.

Memory signs will be alternatively called a *prototype*. Such signs are specific representations of signs emerging from the recognition of perceived qualities. There is some evidence that such a representation could be generated by a Galois connection ([11]) however this aspect is beyond the scope of the present paper.

The collections of qualities generating the semantic qualisigns of the sample phenomenon are defined as follows.

a= "observed rabbit" (the observed continuant qualities of the running rabbit, for example, a grayish form, long ears);

a'= "prototype rabbit" (memory knowledge about a rabbit, for example, the parts of the rabbit's body(2), that a rabbit can be a prey(3));

b= "observed motion" (the observed occurrent qualities of the rabbit's motion, for example, that it is moving fast and in a rabbit-like fashion);

b'= "prototype motion" (memory knowledge about the domain of the observed rabbit-like motion like hopping(1), walking(1), running(1) and escaping(3)).

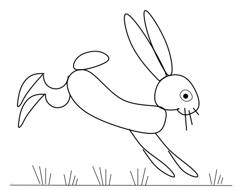

Fig. 6. A rabbit on the run

By using the above collections, sign generation will proceed as follows (the quotes around the qualisign symbols are now omitted).

Qualisign A=a∗a': observed rabbit ∗ parts of body, ¬A=a+a': observed rabbit + prey, B=b∗b': observed motion ∗ running ∗ escaping, ¬B=b+b': observed motion + hopping + walking.

The qualisign A refers to the observed rabbit and its parts of body as a whole which can be simplified as *rabbit(ness)*; ¬A refers to the potential function of the observed rabbit as a prey, briefly *prey* (here, we capitalize on the common reference of the signs linked by the "+" relation); B can be summarized as *escaping* (remember that running(1) is contained in the meaning of escaping(3)); ¬B denotes *rabbithood* from the point of view of motion. Let us mention that the qualities of the physical background of our observation like the grass in which the rabbit is running can be represented by the complementary signs, ¬A and ¬B. In our sample specification such qualities will be omitted.

Icon A+B: *rabbit* and *escaping* are related, but at the same time, separately observable 'parts' of the given phenomenon.

Sinsign A∗B: *rabbit* and *escaping* appear simultaneously and form some unity, for example, the concept of 'rabbit-like-running', which is observed as a single event that happens 'now'.

Index ¬A+¬B, ¬A∗¬B: the signs of the complementary context in which the observed phenomenon is embedded.

Rheme $A*\neg B$: *rabbit∗rabbithood*, the observed rabbit completed by memory knowledge about rabbithood, more specifically, by properties of the prototype of a rabbit which are related to motion. For example, we observed the form and color of a rabbit, and by now we know that a rabbit can also hop and walk. Because such properties are only prototypically defined, the rheme sign will denote an abstraction of the actual rabbit, or briefly, an *abstract rabbit*.
$\neg A*B$: *prey∗escaping*, the sign of a rabbit-like galloping motion, or briefly, *abstract running*. Here, 'galloping' is the sign of a secondness category phenomenon contained in the meaning of escaping; *prey* has a common reference with *rabbit*.

Legisign $A*\neg B+\neg A*B$: the concepts of *abstract rabbit* and *abstract running* are separately observable views of one and the same phenomenon. This aspect is expressed by the legisign via the listing representation of those abstractions as a sign.

Dicent $A+\neg B$: *rabbit+rabbithood*, which sign emerges via the complementation of the rheme ($\neg A*B$) by the context. The continuant qualities that complement the occurrent ones of that abstract sign refer to the actually existing *rabbit*. Due to the prototypical nature of the rheme, the corresponding occurrent qualities are only available via the complementary sign, *rabbithood*. Although the two collections implicate each other (logically), they are not interrelated in the sense of an event. This explains the listing representation of these qualities as the sign of the actual rabbit and a rabbit-like motion, or briefly, the concept of *rabbit-running*.
$\neg A+B$: *prey+escaping*, which denotes the observed rabbit-like motion and the specific properties of a rabbit identified as a prey. This sign can be said to refer to the concept of *escaping-rabbit-as-a-prey*, or briefly, *running-as-a-rabbit*.

Symbol $A*B+\neg A*\neg B$: *rabbit∗escaping+prey∗rabbithood*, which is the conception of the input as the property *running-as-a-rabbit-escaping-as-a-prey*.

Argument $A(\neg A)$ *is* $B(\neg B)$: *rabbit is escaping* in the context of the complementary signs which can be alternatively formulated as *a-rabbit-on-the-run*.

Let us finally remark that the above example also illustrates how the duality of the representation of the input can be efficiently used. An example is 'running' (an occurrent quality) and the momentary, snapshot-like representation of the *same* phenomenon as a 'grayish form' (a continuant quality).

6 Language

In [8] we introduced a model for syntactic signs on the basis of a sequential version of our model of Boolean logical signs. In that framework of syntax, a sentence as a proposition sign emerges from the input words, which sequentially appear as qualisigns, each representing an individual universe.

If we go beyond syntax and our goal is to find out the 'real' phenomenon (and the corresponding qualisigns) signified by the language input, then we may need to handle semantical and syllogistic logical signs ([9]), and possibly, reasoning signs as well. The goal of this paper is of course far more modest. We will only concentrate on semantic signs and their differences with syntactic ones in the positive sense. In this section, we will refer by semantic signs to language symbols from the semantic point of view.

From our definition of semantic signs it follows that semantic and syntactic signs must be isomorphic also in the case of language. Akin to syntax, also semantic sign interactions can be defined in terms of the relational need of signs ([8]). This implies that, from the semiotic point of view, the differences between syntax and semantics are indeed minimal. This conclusion is analogous to the one of the traditional approach, according to which, the semantic structure is compositionally 'built upon' the syntactic one.

There is, however, an interesting difference between the meaning of syntactic and semantic relational needs. Contrary to syntax, in which the relational need of a sign is defined in terms of the nine sign classes, the semantic relational need of a symbol is specified in terms of its category aspect. This difference between syntactic and semantic signs follows from the fact that the syntactic meaning of a language symbol (i.e. a denotation) is more simple and, therefore, typically more specifically defined than the semantic one.

Following our model of syntactic signs, a sign interaction always occurs between two signs, one of which is relationally 'active' and triggering the interaction, and another which is relationally 'passive'. In the case of semantic signs, however, a sign interaction is defined as a 'qualification' of the relation between two signs which are *equal*. For example, the semantic sign 'a stove is black' can denote 'a stove' which 'is black', or equivalently, 'blackness' which has 'a stove' as its object. Which one of the possible interpretations is actually realized, can be derived from the corresponding syntactic sign interaction.

We conclude that, metaphorically, the meaning of syntactic signs amounts to the determination of some sort of a 'topology' characterizing the perceived phenomenon. Semantic signs, on the other hand, are concerned with the 'qualification' of the syntactic sign interactions found, that is, with the determination of those qualities (cf. knowledge) that allow for the conception of the complex relatedness of an observation as a 'real' phenomenon.

The semantic qualification of a sign interaction capitalizes on our memory knowledge. For example, "Socrates is mortal" because we *know* that "Socrates" and "is mortal" are compatible signs which can simultaneously define the sign of a phenomenon. Sometimes the meaning of a semantic qualification is 'trivially' simple. The identification of such cases as a rule, is likely to be the driving force behind the definition of syntactic signs. An example for such a case is the SV(O) rule of English.

With respect to the modeling of semantic relational needs we refer to [9]. As mentioned earlier, the semantic qualities of a language symbol are defined in our model in terms of the symbol's category aspect. A few examples are the following: a noun can denote something existing(1), some reference(2) and something symbolic(3) like the agent of the sentence; a verb can refer to an act of existence(1), a state(2) and a transition(3).

Referential and quantificational properties are considered semantic qualities as well. Signs which are semantically each other's counterparts, are called 'converses' ([9]). Such signs are the linguistic representations of the concept of duality. For example, the verb 'escape' and the nominal 'running' are converses of each other: if we observe escaping to happen, then there can be something present which is in the state of running.

Finally we mention that the possibility for a relation between semantic qualities and Peirce's categories has been experimentally justified by the analysis of adjective–noun combinations ([2]). It is argued that in such combinations one can distinguish between three types namely, intersective (e.g. *yellow car*), subsective compatible (e.g. *interesting car*) and subsective incompatible (e.g. *fast car*). One can easily recognize in these combinations the category aspects of signs. For example, the aspect of firstness is present in the iconic meaning of *yellow*; the one of secondness in the indexical reference of *interesting*; and the one of thirdness in the symbolic meaning of *fast*.

An intersective adjective–noun combination refers to a firstness category phenomenon of something independently existing. A *yellow car* is referring to such a 'thing', which is both *yellow* and (is a) *car*. A subsective compatible one includes a link between two meaningful units. There may be various *car*s around, but we select one of them, by pointing to it, by *interesting*. A subsective incompatible combination refers to a meaning which involves the application of some form of a rule as a property. A *car* can be *fast*, because the concept of the car involves the meaning of velocity which can be modified by *fast*, in the intersective or subsective compatible sense of a combination.

The findings obtained in the experiments ([2]) testing the semantic interpretation of the three types of combinations show the differences in terms of computational complexity with intersective combinations being the simplest and the two subsective types being progressively more complex.

Summary and further research

A Peircean model of semantic signs is introduced on the basis of Boolean logical signs. It is argued that the two systems of signs are isomorphic. An analogous result is reported about syntactic and semantic language signs. By assuming that the collection of the semantic qualities of language signs can be defined as a finite set (akin to their syntactic relational need) it can be proved that the complexity of syntactic and semantic sign recognition are equivalent ([8]).

In [9] we introduced a model for the extension of semantic signs with the mechanism of syllogism. The next step towards a complete representation of (human) knowledge would be the definition of a Peircean model of reasoning signs which is the subject of an ongoing project.

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