Abstract. The paper concentrates on the problem of adequate reflection of fragments of reality via expressions of language and inter-subjective knowledge about these fragments, called here, in brief, language adequacy. This problem is formulated in several aspects, the most general one being: the compatibility of the language syntax with its bi-level semantics: intensional and extensional. In this paper, various aspects of language adequacy find their logical explication on the ground of the formal-logical theory of syntax $T$ of any categorial language $L$ generated by the so-called classical categorial grammar, and also on the ground of its extension to the bi-level, intensional and extensional semantic-pragmatic theory $ST$ for $L$. In $T$, according to the token-type distinction of Ch. S. Peirce, $L$ is characterized first as a language of well-formed expression-tokens ($wfe$-tokens) – material, concrete objects – and then as a language of $wfe$-types – abstract objects, classes of $wfe$-tokens. In $ST$ the semantic-pragmatic notions of meaning and interpretation for $wfe$-types of $L$ of intensional semantics and the notion of denotation of extensional semantics for $wfe$-types and constituents of knowledge are formalized. These notions allow formulating a postulate (an axiom of categorial adequacy) from which follow all the most important conditions of the language adequacy, including the above, and a structural one connected with three principles of compositionality.

Keywords: token-type distinction, categorial grammar, intensional semantics, meaning, interpretation, constituent of knowledge, extensional semantics, referring, ontological object, denotation, categorization, compatibility of syntax and semantics, algebraic models, truth, compositionality, communication.

1. Introduction

In the process of cognizing reality, we acquire knowledge about it, gathering knowledge in a certain system and representing it in some sign system, usually a language-based one (see Diagram 1). In the language system of representation, this knowledge is processed, leading to a new knowledge about the reality of interest to us, thus to a better cognition of it.
Urszula Wybraniec-Skardowska

Diagram 1. Representation of knowledge

The effectiveness of cognition is dependent on mutual relations between the three elements of the triad:

**Language – Knowledge – Reality.**

This is obtained when the syntax of language reflects, in an adequate manner, its semantics, and thus the suitable fragment of the cognized reality, as well as the knowledge being the result of inter-subjective cognition.

2. The problem area of language adequacy

The problem of language adequacy in relation to cognition is, beside that of adequacy of cognition, one of the central, traditional philosophical problems. The question of adequate reflection of fragments of reality via expressions of language and inter-subjective knowledge about these fragments is called here, in brief, *language adequacy*. This problem can be formulated in several aspects, the most general one being: *the compatibility of the language syntax with its bi-level semantics:*

- *intensional semantics,*

in which to expressions of language correspond – as constituents of knowledge – their meanings (*intensions*),
On language adequacy

and

extensional semantics,

in which to these expressions correspond – as ontological objects of reality – their object references (references) and denotations (extensions).

Diagram 2. Semantic adequacy

The problem area of language adequacy (discussed in Section 4 of this paper) will be considered formally on the ground of the logical theory of syntax $T$ (outlined in Section 3.1 of this paper) and its extension to the semantic theory $ST$ (characterized in Section 3.2 of this paper), describing the bi-level semantics of categorial language. The theories $T$ and $ST$ are presented in the author’s papers (1985, 1989, 1991, 1998, 2005–2009) and are built in the spirit of Leśniewski’s (1929, 1930) and Ajdukiewicz’s (1935, 1960) theories of syntactic (semantic) categories, with simultaneous retention of Frege’s ontological canons (1879).

In the theory of syntax $T$, the notion of a well-formed expression (meaningful) and that of the syntactic category are defined. In the semantic theory $ST$ – with reference to Frege’s (1892) distinction: Sinn–Bedeutung, or Carnap’s (1947): intension–extension – such notions as: meaning (intension) of a meaningful expression, its interpretation, its object reference (reference), as well as denotation (extension) are defined, and also two notions of semantic category: the notion of intensional category and that of extensional category are introduced.
The meanings (intensions) of rational expressions are treated as certain constituents of inter-subjective knowledge: logical notions, logical judgments, operations on such judgments or on such notions, on the former and the latter, on other operations.

Object references (references) of language expressions, and also constituents of knowledge, are objects of the cognized reality: individuals, states of things, operations on the indicated objects, and the like. Denotations (extensions) of meaningful expressions of language and constituents of knowledge are sets of such objects. Semantic adequacy – the agreement of these denotations – is illustrated in Diagram 2.

Semantic adequacy is one of the aspects of language adequacy, taking into account the bi-level semantic.

3. An outline of the theory of categorial language

In this paper, various aspects of language adequacy find their logical explication on the ground of the formal-logical theory $T$ of any categorial language, describing its syntax, and also on the ground of its extension to the theory $ST$, describing the bi-level semantics (intensional and extensional) for such a language. The theories $S$ and $ST$ are based on first order predicate logic and set theory.

Let $L$ be any, yet – in our consideration – an established language characterized categorially. The language $L$ is defined when the set $S'$ of all its well-formed expressions, and its subset $S$ of meaningful expressions, is determined, satisfying the requirements of categorial syntax and categorial semantics.

3.1. Categorial syntax – Theory $T$

3.1.1. General characteristics of the categorial language

The theory $T$ of the syntax of the language $L$ is built on the basis of Husserl’s idea of pure grammar (1900–1901) and in accordance with the general assumptions of Leśniewski’s (1929, 1930) and Ajdukiewicz’s (1935, 1960) theories of syntactic (semantic) categories. The language $L$, syntactically characterized in it, can be precisely defined as a categorial language; that is, as a language all of whose well-formed expressions of the set $S'$ (briefly $wfe$ of $S'$) are generated by a categorial grammar, the idea of which originated from Ajdukiewicz (1935, 1960) and which has already had a long history (see Bar-Hillel, 1950, 1953, 1964; Lambek, 1958,
On language adequacy


A characteristic feature of the categorial language \( L \), generated by the classical categorial grammar, is that each \( wfe \) of the set \( S' \) has a functor-argument structure, that it is possible to distinguish in it the main part – the so-called main functor, and the other parts – called arguments of this functor, yet each constituent of a meaningful expression of \( S \) has a determined syntactic category and semantic categories (extensional and intensional), can have a meaning assigned to it, and thus also a category of knowledge (the category of constituents of knowledge), and also denotation, and thus – an ontological category (the category of ontological objects).

The syntactic categories of \( wifes \) of \( L \), and also the indicated categories corresponding to them, are determined by attributing to them categorial indices (types) which were introduced by Ajdukiewicz (1935) into logical semiotics with the aim of determining the syntactic role of expressions and of examining their syntactic connection, in compliance with the principle of syntactic connection (\( Sc \)), which will be discussed below.

The categorial indices are, however, useful not only while establishing and examining syntactic connection of \( wifes \) of \( L \). They appear simultaneously in the role of a tool coordinating meaningful expressions and metalanguage objects (see Suszko, 1958, 1960, 1964; Ajdukiewicz, 1960; Stanosz & Nowaczyk, 1976); they also serve to describe categorial adequacy – a main aspect of language adequacy.

**The principle of syntactic connection** (\( Sc \)), which makes reference to the principle applied by Ajdukiewicz, can be formulated freely in the following way:

\[
(Sc) \quad \text{If } e \text{ is a functor-argument expression of the language } L, f \text{ is the main functor of the expression } e, \text{ and } e_1, e_2, \ldots, e_n (n \geq 1) \text{ are subsequent arguments of the functor } f, \text{ then if } a \text{ is a categorial index of the expression } e, \text{ while } a_1, a_2, \ldots, a_n \text{ are categorial indices of subsequent arguments of the functor } f, \text{ then the categorial index of the functor } f \text{ is formed out of the index } a \text{ of the expression } e, \text{ which the functor forms, as well as out of the subsequent indexes } a_1, a_2, \ldots, a_n \text{ arguments of this functor.}
\]
In the quasi-fractional notation applied by Ajdukiewicz, the index of the functor $f$ is the following fraction:

$$a/a_1a_2\ldots a_n.$$ 

And thus, for example, the expression:

*Warsaw is the capital of Poland*,

in which ‘*is*’ is distinguished as its main functor, with the categorial index $s$ assigned to sentences, satisfies the principle $(Sc)$, since the functor ‘*is*’, with the subsequent arguments which are the names ‘Warsaw’ and ‘the capital of Poland’, and the categorial indices $n$ and $n$, as a sentence-forming functor with arguments being names, has the categorial index $s/nn$, formed out of the index $s$ and the indices of its subsequent arguments.

In the formal definition of a *wfe*, it is required that each complex functor-argument constituent of the given expression should satisfy the principle $(Sc)$. As regards our instance of the sentence, this principle must also be satisfied by the expression ‘*the capital of Poland*’.

The set $S'$ of all *wfes* of $L$ is defined in the axiomatic theory $T$ of categorial syntax, with the help of primitive notions of this theory.

### 3.1.2. Two levels of formalization of categorial syntax

Formalization of the theory $T$ runs on two levels. In accordance with the distinction by Peirce (1931–1935): *token-type* of signs, the double ontological nature of signs of the language $L$ is taken into account in it.

On the ground of the theory $T$, the language $L$ is syntactically characterized as:

– a language of expression-*tokens* – on the first level, the *level of tokens* and

– a language of expression-*types* – on the other level, the *level of types*.

*Tokens* of the signs of $L$ are a starting point in formalization of the theory $T$. They are intuitively understood as concrete, material, empirical, spanning over time and space, objects perceived through senses. Usually, though not necessarily, they are graphical signs. They can appear on paper, on a school blackboard, on computer screens. They can be illuminations of light on advertising billboards, smoke signals, arrangements of objects, e.g., configurations of stars, compositions of flowers, stones, and the like.

The method of conceptualization, which leads to formalization of knowledge about language within an independently fixed temporal range of considerations and a freely-established area of language-based communication, allows isolating (extracting) a *set-universe* of sign-*tokens* which are used in this communication.
Types of the signs of the language $L$ are its secondary objects. In the theory $T$ they are defined by means of tokens of a determined universe. They are abstract objects, whose concrete realizations are tokens. The types are understood as set-theoretical sets, classes of tokens remaining in a broadly-understood identifiability relation between one another (defined, obviously, on the given universe). The notion of identifiability is the result of the conceptualization process (notioning) of knowledge, with the same manner of use of sign-tokens (making use of these signs) in a selected fragment of the system of communication between human beings.

3.1.3. The foundations of the formal theory $T$ – the level of tokens

The theory $T$ built on the level of tokens is an axiomatic theory, including the concretistic categorial characteristics of the language $L$. Its primitive notions on the level of tokens are:
- the universe $U$ of all sign-tokens of $L$,
- the binary relation $\sim$ of identifiability of tokens of the set $U$,
- the ternary relation $c$ of concatenation, defined on tokens of the set $U$,
- the initial vocabulary $V_0^1$ of $L$,
- the auxiliary initial vocabulary $V_0^2$ for $L$, containing a set of categorial indices,
- the binary relation $i$ of indicating indices to word-tokens of $L$,
- the binary relation $r_1$ of forming functor-argument expression-tokens of $L$,
- the binary relation $r_2$ of forming indices of functor-tokens of $L$.

The system of axioms which characterize the primitive notions of the theory $T$ are given in the author’s works (1985, 1989, 1991, 2006). It is postulated about the universum $U$ of sign-tokens of $L$ that it is a non-empty set, about the relation $\sim$ of identifiability – that it is an equivalence relation in the universe $U$. It is not assumed about the concatenation relation $c$ that it is a function: a concatenation of two tokens is a complex token, formed out of two tokens identifiable with them, respectively, and also each token identifiable with it. For example, the concatenation of two word-tokens:

**semiotics**

**logical**

the right and the left ones, of different fonts, thickness and size of type, is both:

the complex word-token:

*Logical Semiotics*
and the word-token:

LOGICAL SEMIOTICS

and also each word-token identifiable with the two complex words.

As regards the initial vocabularies $V^1_0$ and $V^2_0$ of $L$, it is postulated that they are non-empty subsets of the universe $U$, out of which the set $W^1$ of all word-tokens of $L$ and the set $W^2$ of all auxiliary word-tokens for $L$ are formed, respectively. The initial vocabularies may contain structural symbols, e.g., brackets or punctuation marks.

Sets of word-tokens $W^1$ and $W^2$ are defined as set-theoretical intersections of all sets including, respectively, the vocabulary $V^1_0$ and the auxiliary vocabulary $V^2_0$, which are closed with respect to the concatenation relation $c$.

The relation $i$ of indicating the indices of word-tokens of $L$ (in short: the indexation or typification relation) is defined on the subset of the Cartesian product $W^1 \times W^2$:

$$i \subseteq W^1 \times W^2.$$ 

Its left domain is a set of word-tokens possessing categorial indices (types), the right one – the set $I$ of indices of such words. This relation is not a function – however, to a word-token there corresponds, with the accuracy to identifiability, one categorial index of the set $I$.

We read the expression $i(w, a)$: $a$ is a categorial index (type) of the word-token $w$.

The proper vocabulary $V^1$ of $L$ is defined as a set of word-tokens of the initial vocabulary $V^1_0$ possessing a categorial index (type), whereas the proper vocabulary $V^2$ auxiliary to $L$ – as a set of auxiliary word-tokens of the vocabulary $V^2_0$, being indices of words of the vocabulary $V^1$.

The left domains of the relations $r_1$ and $r_2$ are, respectively, a set of finite tuples of word-tokens of the set $W^1$ possessing indices from the set $I$ and a set of finite tuples of indices of such words. The relations $r_1$ and $r_2$ are not functions, but assign to any finite tuple of word-tokens possessing indexes, or, respectively, to any tuple of indices of word-tokens, with the accurate to identifiability, one complex word-token called functor-argument expression-token, or, respectively, one index of the functor.

We read the expression

$$(e) \quad r_1(f, e_1, e_2, \ldots, e_n; e)$$

as follows: $e$ is a functor-argument expression-token composed of the main functor $f$ and its subsequent arguments $e_1, e_2, \ldots, e_n$. 

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The expression 

\begin{equation}
  r_2(a, a_1, a_2, \ldots, a_n; a_f)
\end{equation}

is read: \(a_f\) is an index of the functor \(f\), formed out of the index \(a\) and subsequent indexes \(a_1, a_2, \ldots, a_n\).

The expression \(e\) in \((e)\) can be treated as a schema representing any expression-*tokens* of \(L\), formed from the functor \(f\) and its subsequent arguments \(e_1, e_2, \ldots, e_n\), irrespective of the concrete rules of the syntax of \(L\), independent of the position which these constituents take in the expression \(e\), and independent of the applied notation, type, etc.

Similarly, the expression \(a_f\) in \((i)\) replaces any index of the functor formed from the index \(a\) and indices \(a_1, a_2, \ldots, a_n\), irrespective of the applied notation of the functor indices, e.g., quasi-fractional, or with the use of brackets, or still any other, applied by researchers of categorial grammars.

The set \(E_{1-a}^1\) of all the functor-argument expression-*tokens* of the language \(L\) (complex expressions of \(L\)) is defined as the right domain of the relation \(r_1\), and the set \(E_{f-a}^2\) of all the indices of functors (complex indices) – as the right domain of the relation \(r_2\), contained in the set \(I\) of index-*tokens*.

The set \(E^1\) of all the expression-*tokens* of \(L\) and the set \(E^2\) of all their index-*tokens* are defined, for \(k = 1, 2\) as the following sets:

\[ E^k = V^k \cup E_{f-a}^k. \]

In the theory \(T\), the principle \((Sc)\) of syntactic connection for the functor-argument expression \(e\), satisfying the formula \((e)\), is formalized by means of the formula:

\begin{equation}
  \forall 1 \leq j \leq n (i(f, a_f) \land i(e_j, a_j) \land i(e, a)) \Rightarrow (i).
\end{equation}

In accordance with axioms of the theory \(T\), for the expression \(e\) satisfying the formula \((e)\) we obtain the following rule corresponding to that of cancelation of indices, applied by Ajdukiewicz (1935) to examine the syntactic connection of expressions:

\[ \forall 1 \leq j \leq n ((i)) \land i(f, a_f) \land i(e_j, a_j)) \Rightarrow i(e, a). \]

In the notation applied by Ajdukiewicz to this formal rule there corresponds the following rule of cancelation indices (*types*):

\[ a/ a_1 a_2 \ldots a_n (a_1, a_2, \ldots, a_n) \rightarrow a. \]
In our given example of the expression:

\[\text{Warsaw is the capital of Poland}\]

and checking whether it is a sentence, the rule takes the form:

\[s/n\,n\,(n,n) \rightarrow s.\]

A reconstruction of the classical categorial grammar on the ground of the theory \(T\) is the system of notions:

\[\Gamma = \langle U, c, \sim, V^1, V^2, i, r_1, r_2, (Sc) \rangle,\]

generating the set \(S'\) of all wfe-tokens of \(L\). The set \(S'\) is defined as follows:

**DEFINITION 1 (the set of all well-formed expression-tokens)**

\[S' = \bigcap \{ X \subseteq E^1 : V^1 \subseteq X \land \forall e \forall f, e_1, e_2, \ldots, e_n \in X(e) \land (Sc_e) \Rightarrow e \in X \}.\]

The set \(S'\) is, thus, the smallest set of expression-tokens containing the vocabulary \(V^1\) of the language \(L\) and each of its functor-argument expression \(e\) such that, providing the structure \((e)\) is preserved, satisfies the principle of syntactic connection \((Sc_e)\).

Each wfe-token of \(S'\) possesses a categorial index which determines its syntactic category. On the level of tokens, the syntactic categories of wfe-tokens are determined by categorial indices of the set \(I\) and are defined as sets of wifes possessing, with the exactitude to identifiability, the same categorial index.

**DEFINITION 2 (syntactic category with the index \(\xi\))**

\[SC_\xi = \{ e \in S' : i(e, a) \Rightarrow a \sim \xi \}.\]

It is assumed that the set \(S'\) is a sum of the set \(B\) of basic expressions of \(L\) (with simple indices (types) of the auxiliary vocabulary \(V^2\)) and the set of functors \(F\) (with complex indices of the set \(E^2_{f-a}\)).

The basic expressions of categorial languages are usually sentences and names. The category of sentences is typically indicated by means of the index \(s\), and the category of names by means of the index \(n\). Complex indices which are assigned to functors are formed from these indices. And so, for instance, the index \(s/nn\) is attributed to sentence-forming functors of two nominal arguments (thus, in particular, the functor ‘is’ in the sentence:
Warsaw is the capital of Poland); on the other hand, the index \( n/n \) – to name-forming functors of one nominal argument (thus, in particular, the functor ‘the capital of’ in the name ‘the capital of Poland’).

The semiotic-logical characteristics of \( L \) on the level of tokens is insufficient. Tokens of expressions indeed appear in the practice of human communication, in acts of language-based communication; nevertheless, in order to explain the very notion of language communication itself in logical pragmatics, it is necessary to have expression-types, and in logical semantics expression-types serve to define the notions of meaning and denotation of language expressions, in logical syntax – to describe grammatical rules.

### 3.1.4. Foundations of the formal theory \( T \) – the level of types

Each set of tokens \( Set \), introduced into formalization of the theory \( T \) on the level of tokens, has – in the theory \( T \) on the level of types – its dual counterpart \( Set \), being a quotient family of equivalent classes of the \( \sim \) identifiability relation, with representatives from the set \( Set \). Thus:

\[
Set = Set/\sim = \{ C : \exists e \in Set(C = [e]_\sim) \}.
\]

Each relation \( r \), introduced into the theory \( T \) on the level of tokens and defined on the tokens, has – in the theory \( T \) on the level of types – its dual counterpart \( r \), determined on types and defined in the following way:

\[
r(e_1, e_2, \ldots, e_n) \Leftrightarrow \exists e_1, e_2, \ldots, e_n \quad (e_1 = [e_1]_\sim \wedge e_2 = [e_2]_\sim \wedge \ldots \wedge e_n = [e_n]_\sim \wedge r(e_1, e_2, \ldots, e_n)), \quad n > 1.
\]

We will give some characteristics of the theory \( T \) on the level of types. Let us note that on the level of types

- to the relation of identifiability \( \sim \), determined on tokens, there corresponds the relation \( = \) of equality of types represented by these tokens,

- to all the other relations of the level of tokens, on the level of types, there correspond relevant relations on types, being set-theoretical functions;

- all the dual counterparts of axioms, definitions and theorems of the theory \( T \), binding on the level of tokens, are theorems of the theory \( T \) on the level of types;

- the categorial language \( L \) on the level of types is characterized by categorial grammar

\[
\Gamma = \langle U, c, V^1, V^2, i, r_1, r_2, (Sc) \rangle,
\]

the notions of which are sets of the types \( U, V^1, V^2 \) and relation-functions \( i, r_1, r_2 \) determined for types.
the principle \((Sc)\) of syntactic connection for functor-argument expression-types is defined in a way similar to that for principle \((Sc)\) for expression-tokens;

the set \(S'\) of all \(wfe\)-types (the set of equivalence classes, of identifiable \(wfe\)-tokens of the set \(S'\)) is generated by grammar \(\Gamma\);

the functor-argument expression-type \(e\) satisfying the formula:

\[
(e) \quad r_1(f, e_1, e_2, \ldots, e_n; e),
\]

and thus built from types: the main functor \(f\) and its arguments \(e_1, e_2, \ldots, e_n\), can be written in the function-argument form:

\[
(e_f) \quad e = f(e_1, e_2, \ldots, e_n),
\]

because each functor \(f\) can be treated as a set-theoretical function determined on finite tuples of word-types of the set \(W^1\), possessing categorial index-types, and taking values in this set (precisely in its subset \(E^1_f-a\));

- If the expression-type \(e\), having the form \((e_f)\), is a \(wfe\)-type (belongs to the set \(S'\)), then in compliance with the principle of syntactic connection \((Sc_e)\) the index of its main functor \(f\), formed out of the index \(a\) of the expression \(e\) and of the subsequent indices \(a_1, a_2, \ldots, a_n\) of the subsequent arguments \(e_1, e_2, \ldots, e_n\) of the functor \(f\), can be written in the quasi-fractional form:

\[
(i_f) \quad i(f) = i(e)/i(e_1)i(e_2)\ldots i(e_n) = a/a_1a_2\ldots a_n.
\]

- Syntactic categories of expression-types of the set \(S'\) are determined by index-types and by the indexation function \(i\) restricted to the set \(S'\) – the function \(i_S\):

\[
SC_\xi = \{e \in S': i_S(e) = \xi\}.
\]

The syntactic category with the index \(\xi\) is a set of all \(wfe\)-types which have the categorial index \(\xi\).

- If \(e\) is a complex \(wfe\)-types of the set \(S'\), formed from the main functor \(f\) and its arguments \(e_1, e_2, \ldots, e_n\), satisfying the formula \((i_f)\), then the functor \(f\) and its index \(i_S(f)\) can be treated as set-theoretical functions which satisfy the equivalence:

\[
(R1) \quad f \in SCa/a_1a_2\ldots a_n \text{ if and only if}
\]
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\( (f) \quad f : SCa_1 \times SCa_2 \times \ldots \times SCa_n \to SCa \land f(e_1, e_2, \ldots, e_n) = e \land \)

\( (i) \quad is(f) : \{is(e_1)\} \times \{is(e_2)\} \times \ldots \times \{is(e_n)\} \to \{is(e)\} \land \)

\( (PCS) \quad is(e) = is(f(e_1, e_2, \ldots, e_n)) = is(f(is(e_1), is(e_2), \ldots, is(e_n))). \)

We call the condition (PCS) the principle of syntactic compositionality. Loosely speaking, this principle says that:

The syntactic category (categorial index) of the well-formed functor-argument expression-types \( e \) of \( L \) is a function of syntactic categories (categorial indices) of arguments of its main functor \( f \); this function is \( is(f) \).

3.2. Categorial semantics – the theory \( ST \)

The theory \( ST \) is an axiomatic theory, built over the theory of syntax \( T \). It describes both the intensional semantics and the extensional semantics of the categorial language \( L \).

3.2.1. Intensional semantics

The basic notions of the intensional categorial semantics of \( L \) are the following:

– the notion of meaning (intension) of a wfe-type of \( L \),
– the notion of a category of knowledge (constituents of knowledge), determined by means of the notion of meaning, and
– the notion of an intensional semantic category, defined by means of the previous notion.

In the semantic, formal characteristics of \( L \), these notions are defined on the level of types. However, introducing into the formal theory \( ST \) the notion of meaning of a meaningful wfe-type of the set \( S \), and also that of interpretation of such an expression, as well as derivative notions, requires making references to some notions of the theory \( ST \) which are introduced on the level of tokens.

There exist various philosophical concepts concerning the nature of the meaning of a language expression, and also various theories of this notion. In the theory \( ST \), the formal concept of meaning is based on the general theory \( TM&I \) of meaning and interpretation, which were presented in the author's works (2005a, b; 2007a, b). This concept is a logical pragmatic-semantic one and has certain connections with the understanding of meaning as a manner of using language expressions. It takes into account the so-called functional approach to language analysis represented by Pelc (1971, 1979).

According to the approach proposed by Pelc, we can speak of a double manner of using language expressions:
regarding the first of them, the manner of using (use) takes place only in given conditionings, in determined situational-language contexts and concerns solely expression-tokens
2) regarding the other one, the manner of using (usage, Use) characterizes the meaning of an expression; this manner is built into the meaning of an expression, while the very expression itself can be treated as isolated, static, torn out of context, e.g., as a dictionary entry; then it is an expression-type, a class of its concrete occurrences, a class of expression-tokens, either applied to represent some object or used in acts of communication and in given situations, with reference to only one broadly-understood object, or with reference to more than one object, still one of the same kind.

The difference between these two manners of using of expressions manifests itself in that two persons can use – in the sense of Use– the same expression-type by means of its two different tokens, thus using its different tokens in the sense of use.

In the set-theoretical formalization of the theory ST it is accepted that use is a relation dealing with real or potential physical acts of object references of wfe-tokens, already performed, being performed, or ones that may be performed by users of L in a determined communication process by means of these expressions. The relation use is a primitive notion of the theory ST, whereas the relation Use, concerning the usage of expression-types by users of L, is a secondary notion of this theory. It is defined by means of the relation use and appears useful in the proposed, formal concept of meaning and interpretation, which makes references to certain ideas of Wittgenstein (1954) and Ajdukiewicz (1931, 1934). This concept is connected with understanding the meaning of expression-types as the Use manner of using them.

The primitive notions of the theory ST, with which the theory of syntax T is enriched are the following:

– the set User of all users of L,
– the set Ont of all extra-language objects, described by L,
– the binary operation use of wfe-tokens of the set S’.

It is assumed only axiomatically about the sets User and Ont that they are non-empty. A user of L, belonging to the set User, can be not only a current, but also a past or future user of it. On the other hand, objects of the set Ont can be not only concrete, material objects, but also fictional or abstract creations described by L. We do not assume anything, either, about categorization of the set Ont. Ontological categories can, but do not have to, be: a category of individuals, categories of sets of individuals, various
categories of set-theoretical relations and functions, a category of situations (states of things), etc.

The relation *use* is understood in a very broad way, as well. It can be an operation of human production (not necessarily external) of expression-tokens, exposing them, or also interpreting with the aim to refer to determined objects of the set *Ont*. Such an operation conceived broadly – within a liberally fixed temporal space and any fixed area of language-based communication between people – is treated as all such physical activities of users of *L*, which are taking place currently, occurred in the past and may – potentially – happen in the future, and which are subject to referring concrete expression-tokens to determined objects of the set *Ont* in relevant situations. The operation *use* can be called a **function of object reference of wfe-tokens of the language *L* by its users**.

We postulate that the operation *use* is a two-argument partial function, whose first domain is the set *User* of users, the second – some proper subset of the set *S'* of all wfe-tokens of *L*, while the counter-domain – the subset of objects of the set *Ont*, to which these expressions are referred. And thus:

**AXIOM 1 (sets: *User, Ont*)**

\[ User \neq \emptyset \text{ and } Ont \neq \emptyset. \]

**AXIOM 2 (** *use**)

*use* is a partial function:

\[ User \times S' \rightarrow Ont, \]

\[ D_1(use) = User \text{ and } D_2(use) \subset S'. \]

We read the expression: *use*(u, e) = o, where u ∈ *User*, e ∈ *S'*, o ∈ *Ont* as follows: uses(produces, exposes) the wfe-token e with reference to the object o. The object o is called an **object of reference** or a **referent** or a **correlate** of the expression e indicated by its user u.

Thus, each user of *L* uses at least one token of an expression of this language with reference to some object, but not every language token must have some object reference (a referent, a correlate).

Let us note, formally, when an expression-token possesses an object reference:

**DEFINITION 3 (possessing a referent)**

*e has an object reference* iff e ∈ *S'* ∧ ∃u ∈ *User* ∃o ∈ *Ont*(use(u, e) = o).

Thus: **Object reference is possessed only by such a wfe-token that is used by some user of *L* with reference to an extra-language object.**
DEFINITION 4 (possessing the same manner of use of tokens)

\( e \simeq e' \) iff \( \exists o \in \text{Ont}[\exists u \in \text{User}(\text{use}(u, e) = o) \land \exists u \in \text{User}(\text{use}(u, e') = o)] \).

Thus: Two wfe-tokens have the same manner of use if and only if they have the same object reference (they have the same referent).

We introduce the relation of using expression-types in the sense \( \text{Use} \) in the following way:

AXIOM 3 (\( \text{Use} \))

\[ \emptyset \neq \text{Use} \subseteq \text{User} \times S' \]

DEFINITION 5 (\( \text{Use} \))

\( u \text{ Use } e \) iff \( \exists e \in e \exists o \in \text{Ont}(\text{use}(u, e) = o) \).

Therefore we postulate as follows: There exists a user of \( L \), who uses a wfe-type, and the user \( u \) uses the wfe-type \( e \) if and only if they use a token of the expression \( e \) with reference to a referent.

The notion of meaning of an expression-type is determined by means of the relation \( \simeq \) of possessing the same manner of Use of expression-types. The notion of meaning is thus defined only for expressions which belong to \( D_2(\text{Use}) = S \subseteq S' \). It is only to such expressions that meaning is assigned.\(^{10}\) We will call the set \( S \) the set of meaningful expressions of \( L \).

DEFINITION 6 (possessing the same manner of Use of types)

\( e \simeq e' \) iff \( \forall u \in \text{User}[\forall \text{use}(u, e) \iff u \text{ Use } e'] \land \forall o \in \text{Ont}(\exists e \in e (\text{use}(u, e) = o) \iff \exists e' \in e' (\text{use}(u, e') = o)) \).

The above-given definition states that: Two meaningful expression types \( e \) and \( e' \) of \( S \) have the same manner of Use if and only if any user of \( L \) Uses one of them, when he/she Uses also the other of them and for each extra-language object it is a referent of some token of the wfe-type \( e \) if and only if this object is also a referent of some token of the other wfe-type \( e' \).

The relation between the two different relations of possessing the same manner of using expressions of \( L \) is formulated by:

THEOREM 1.

\[ \exists u \in \text{User} (u \text{ Use } e) \land e \simeq e' \Rightarrow \exists e \in e \exists e' \in e' (e \simeq e') \],

in compliance with which: If the two used expression-types \( e \) and \( e' \) of \( S \) have the same manner of using types (in the other sense, the one of \( \text{Use} \)),
then there exist their relevant tokens $e$ and $e'$, which also have the same manner of using, but one that is proper to tokens (the manner of using in the first sense, the one of use).

Let us note that in accordance with the introduced definition of the relation $\cong$ we can state that:

**THEOREM 2.**

Relation $\cong$ is an equivalence relation in the set $S$.

We define the basic notion of intensional semantics for $L$, i.e., the notion of **meaning (intension) of any meaningful wfe-type** $e$ of $L$ as the equivalence class of relation $\cong$, determined by this expression:

**DEFINITION 7 (meaning of the expression-type $e$)**

$$\mu(e) = [e]_{\cong} \text{ for every } e \in S.$$  

The meaning $\mu(e)$ of wfe-type $e \in S$ may be intuitively understood as a common property of all these wfe-types which possess the same manner of using (Use) as that of $e$. This common property can be called the **manner of using Use of expression-type** $e$.

The **meaning of the wfe** $e \in S$ can be determined also as an equivalence class of all expression-types being **synonyms** of the expression $e$, and thus having the same meaning as that of $e$, the same manner of using (Use) as that of $e$.

It follows from the definition of **meaning** of a meaningful expression-type that there is exactly one meaning – the **global meaning** – that corresponds to such an expression. It needs, however, to be observed that since a wfe-type is a class of all **identifiable** expression-tokens (the fixed universe $U$), used in any time interval considerations and any established area of language communication, its global meaning can consist of several meanings determined by its **subtypes** – its subsets of **identifiable tokens**. For example, in the English language, the global meanings of the individual word-types: “logic”, “key”, “profession”, or “leak” treated as classes of equiform, identifiable tokens, consist of, at least, two meanings ascribed to certain of their subtypes. These words are ambiguous and as such do not have one fixed meaning.

The notion of ambiguity is introduced into the theory $ST$ by means of that of **denotation** – a notion of **extensional semantics**. The notion of **not possessing an established meaning**, on the other hand, is determined by the definition:
DEFINITION 8 (not possessing an established meaning)

\( e \) does not possess an established meaning iff

\[ \neg \forall e' \subseteq e \ (\mu(e') = \mu(e)), \]

i.e.,

\[ \exists e' \subseteq e \ (e' \neq e \land \mu(e') \neq \mu(e)). \]

There follows from the definition, in particular:

THEOREM 3.

a. \( e \) does not have an established meaning iff \( \exists e_1, e_2 \ (e_1 \subseteq e \land e_2 \subseteq e \land e_1 \neq e_2 \land \mu(e_1) \neq \mu(e_2)), \) i.e., there exist two subtypes of the \( wfe \)-type \( e \) with different meanings.

b. If \( e \) does not have an established meaning, then \( \exists u \in \text{User} \ \exists e_1, e_2 \in e \ \forall o \in \text{On} \ (\neg((\text{use}(u, e_1) = o = \text{use}(u, e_2))), \)

i.e., there exists a user of \( L \), who does not use at least two tokens of the expression \( e \) with reference to the same extra-language object.

c. If \( \exists e_1, e_2 \in e \ (\neg(e_1 \approx e_2)) \), then \( e \) does not have an established meaning.

In compliance with condition c. of Theorem 3: Expression-type does not have an established meaning when some two of its tokens are not used in the same manner.

The given definition of \textit{meaning} of an expression-type determines at the same time the \textit{operation of meaning} \( \mu \) as the following mapping:

\[ \mu : S \to 2^S \]

of the set \( S \) of all meaningful expression-types of the language \( L \) into a family of all of its subsets. We call the image of the set \( S \) under the operation \( \mu \) the \textit{set of constituents of knowledge} and denote it by \( K \). Thus:

\[ K = \mu(S). \]

The operation of meaning \( \mu \) corresponds to the \textit{operation of interpretation} \( \iota \) defined as mapping:

\[ \iota : S^* \to 2^S \]

defined by the formula:

\[ \iota(e) = [e]_{\approx 1}, \text{ for any } e \in S^* \subseteq S; \]
where $\cong_1$ is a relation of possessing the same manner of interpreting meaningful expression-types and a sub-relation of the relation $\cong$ of possessing the same manner of using (Use) such expressions.\textsuperscript{11}

**Interpretation of a meaningful expression-type** can be intuitively understood as a common property of all the meaningful expression-types which possess the same manner of interpreting.

It is well-known that if an expression-type is intermediary in language communication, its interpretation can differ from its meaning. Let us note that formally we can merely state that for any meaningful expression-type $e$

$$i(e) \subseteq \mu(e).$$

We can divide the set of constituents of knowledge $K$ into categories of knowledge, like we have divided the set of wfe-types of $L$ into syntactic categories. In order to do so we make use of categorial indices of the set $I$ and introduce the function of indexation $i_K$ of components of knowledge:

$$i_K : K \rightarrow I.$$

We define the category of knowledge with the index $\xi$ in the following way:

$$K_\xi = \{k \in K : i_K(k) = \xi\}.$$

If, in $L$, we have sentences, names, and functors-functions defined on them, then their meanings – as constituents of knowledge – determine, respectively, the category of logical judgments, the category of logical notions, and categories of operations on logical judgments and/or logical notions.

In the semantic, **intensional** description of $L$, we count wfe-types of $L$ to suitable intensional semantic categories determined by categorial indices. And so, we are introducing the following definition:

$$\text{Int}_\xi = \{e \in S : i_K(\mu(e)) = \xi\} = \{e \in S : \mu(e) \in K_\xi\},$$

i.e., the **intensional semantic category with the index** $\xi$ is a set of all these meaningful expression-types of $L$, whose meanings belong to the category of knowledge with the index $\xi$.

One of the conditions of **language adequacy** is an agreement of syntactic categories with semantic categories, and this of both intensional and extensional ones. We will introduce the latter formally on the second level of language semantics of the language $L$. 

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3.2.2. Extensional semantics

In compliance with Frege’s distinction (1892): Sinn–Bedeutung and Carnap’s distinction (1947): intension–extension, we distinguish the meaning of expression-type of $L$ from a denotation of such an expression. We introduce the notions of denotation (extension) of an expression-type and that of denotation of a constituent of knowledge, corresponding to this expression, formally on the basis of the theory $ST$, by means of respective notions of denoting (reference). All these notions belong to the semantics of the second level – the extensional semantics of $L$.

Denoting (reference) $\text{Ref}_1$ is a binary relation that holds between expression-types and extra-language objects of the set $\text{Ont}$. The notion of denoting can, however, also be introduced as the relation $\text{Ref}_2$ holding between constituents of knowledge and extra-language objects of the set $\text{Ont}$. Therefore, formally:

$$\text{Ref}_1 \subseteq S \times \text{Ont} \text{ and } \text{Ref}_2 \subseteq K \times \text{Ont},$$

and the definitions of these relations are as follows:

**DEFINITION 9 (denoting)**

a. $\text{e Ref}_1 \text{ o}$ iff $\exists u \in \text{User} \exists e \in e \ (\text{use}(u,e) = o)$, where $e \in S$.

b. $\text{k Ref}_2 \text{ o}$ iff $\exists e \in S \ (k = \mu(e) \land e \text{ Ref}_1 \text{ o})$, where $k \in K$.

The expression-type $e$ denotes the object $o$ if and only if there exists a user of $L$, who uses any token of the expression $e$ with reference to the object $o$, whereas the constituent of knowledge $k$ denotes the object $o$, when there exists a meaningful expression of $L$ determining $k$ and denoting $o$. We will refer to the objects denoted by expression-types or constituents of knowledge as their denotates.$^{12}$

As an example, the denotate of the name “a computer” is each computer; any computer is also denoted by the notion ‘a computer’; any computer is thus a denotate of this notion as well.

It is easy to notice that the denotate of an expression-type is, at the same time, an object reference of a token.

The set of all denotates of an expression-type or, respectively, a constituent of knowledge, is called its denotation or extension. Thus:

**DEFINITION 10 (denotation)**

a. $\delta(e) = \{ o \in \text{Ont} : e \text{ Ref}_1 \text{ o} \}$, where $e \in S$.

b. $\delta_K(k) = \{ o \in \text{Ont} : k \text{ Ref}_2 \text{ o} \}$, where $k \in K$. 

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The *denotation* of a meaningful expression-type or a constituent of knowledge corresponding to it does not have to be a non-empty set. It is such a set when a user of $L$ *uses* the same expression-type; that is, he/she *uses* any of its *tokens* with reference to an extra-language object. Hence, we have:

**THEOREM 4 (the criterion of non-emptiness of denotation)**

$$\exists u \in \text{User} \ (u \ \text{Use} \ e) \iff \delta(e) \neq \emptyset \iff \delta_K(\mu(e)) \neq \emptyset.$$  

The definitions of *denotation* of a meaningful expression-type given below and the constituent of knowledge corresponding to it cover the so-called *global denotation*. Inasmuch as an expression-type is ambiguous, its *global denotation* is composed of *denotations* determined by its unambiguous *sub-types*.

When the *denotation* of a meaningful expression-type or a constituent of knowledge corresponding to it is a one-element set (a singleton), we identify it sometimes, in practice, with its sole *denotate*. This is so, for instance, when we come to deal with proper names. Let us note that in situational semantics, *denotates* of logical sentences are conceived as situations and frequently identified with *denotations* of such sentences. Also, in Frege's traditional semantics (1892), a *denotate* and – at the same time – *denotation* of a logical sentence is its logical value, i.e. truthfulness or falsity.

Let us note, too, that *denotations* of the so-called general names (predicative) and the logical notions corresponding to them, are called *scopes*, identifying the latter. For example, the scope (*denotation, extension*) of the name “a computer” – that is – the set of all computers, is identified with the scope (*denotation*) of the notion ‘a computer’. This agreement of the denotations of names and notions corresponding to them is connected with *language adequacy*, and more precisely – with *semantic adequacy*, which is illustrated by Diagram 2.

In the theory $ST$, there holds a theorem which frames this adequacy:

**THEOREM 5 (semantic adequacy)**

$$\delta(e) = \delta_K(\mu(e)), \quad \text{for any } e \in S.$$  

According to Theorem 5: *Denotations of any meaningful expression-type of $L$ and the meaning (a constituent of knowledge) of this expression are in agreement.*

There follows immediately an important theorem from this theorem, pointing to the fact that the *meaning* of an expression-type determines its *denotation*:
THEOREM 6 (dependence between the meaning and denotation)

\[ \mu(e) = \mu(e') \Rightarrow \delta(e) = \delta(e'), \quad \text{for any } e, e' \in S. \]

According to this theorem: If two expression-types have the same meaning (intension), then they also have the same denotation (extension). In other words: If two expressions are synonymous, then they are extensionally equivalent.

The reverse theorem does not hold: two expressions can have the same denotation (be extensionally equivalent), but may not have the same meaning (may not be synonymous). Instances of such expressions are: the “Morning Star” and the “Evening Star” (see Frege, 1892).

The two conclusions below follow from the above theorem, in particular:

COROLLARY 1.

If \( \exists o \in \text{Ont} \ (e_1 \ \text{Ref} \ o \land \neg e_2 \ \text{Ref} \ o \lor e_2 \ \text{Ref} \ o \land \neg e_1 \ \text{Ref} \ o) \),
then \( \mu(e_1) \neq \mu(e_2) \).

COROLLARY 2.

Any expression-type does not possess an established meaning, when there exist two such subtypes of it that an object is the denotate of only one of them.

Following Corollary 1: Two expression-types do not have the same meaning as long as an object is the denotate of only one of the expressions.

In accordance with the other conclusion, for example, the ambiguous name “a key” does not possess an established meaning, since there exists “a key” which is the denotate of a certain subtype of this name, yet which is not the denotate of another subtype of this name.

The given definitions of the denotation of an expression-type and the denotation of a constituent of knowledge determine simultaneously two denotation operations: \( \delta \) and \( \delta_K \). They are the following mappings:

\[ \delta : S \rightarrow 2^{\text{Ont}} \quad \text{and} \quad \delta_K : K \rightarrow 2^{\text{Ont}}, \]

respectively: of the set \( S \) of all meaningful expression-types of \( L \) into the family of all subsets of the set of extra-language objects \( \text{Ont} \) and of the set \( K \) of all constituents of knowledge into this family.

Thus, it follows from Theorem 5 of semantic adequacy that the denotation operation \( \delta \) is a composition of denotation operation \( \delta_K \) and the meaning operation \( \mu \) that is (see Diagram 2): \( \delta = \delta_K \circ \mu \).
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The image of the set \( S \) with respect to the operation \( \delta \) and the set \( K \) with respect to the operation \( \delta_K \), are called a set of ontological objects and denoted by \( O \). Thus (see Diagram 2):

\[
O = \delta(S) = \delta_K(K).
\]

We can divide the set \( O \) of ontological objects into ontological categories, in a similar way as we divided the set \( S \) of meaningful expressions of \( L \) into syntactic categories, and the set of constituents of knowledge \( K \) into categories of knowledge. For this purpose we use the categorial indices of the set \( I \) and introduce the function of indexation \( i_O \) of ontological objects:

\[
i_O : O \rightarrow I.
\]

We define the ontological category with the index \( \xi \) in the following way:

\[
O_\xi = \{ o \in O : i_O(o) = \xi \}.
\]

If, in \( L \), we have sentences, individual names, and functor-functions defined on them, then the ontological objects corresponding to them – as their denotations – determine, respectively, a category of states of things (in Frege’s semantics – a category of logical values), a category of individuals, and a category of operations on states of things (resp., on logical values), on individuals, on the former and/or the latter, etc.

In the semantic, extensional description of \( L \), the meaningful expression-types of this language count into respective extensional semantic categories, determined by categorial indices. And so:

\[
Eks_\xi = \{ e \in S : i_O(\sigma(e)) = \xi \} = \{ e \in S : \sigma(e) \in O_\xi \},
\]

i.e., the extensional semantic category with the index \( \xi \) is a set of all the expression-types of \( L \), whose denotations (extensions) belong to the ontological category with the index \( \xi \).

One of the conditions of language adequacy is an agreement of syntactic categories with applied semantic categories, and this both intensional as well as extensional. This agreement is not ensured by the agreement of both levels of the semantics of \( L \): intensional and extensional.

In the next part of the paper, we will consider, with more precision, the problem area of language adequacy, discussing its various aspects.
4. Language adequacy and its aspects

In the Introduction, we defined the problem area of language adequacy in a most general manner, as a compatibility of language syntax and its bi-level semantics: intensional semantics and extensional semantics. Formal consideration of the problem of language adequacy can be conducted on the basis of the theory of syntax $T$ and its extension to the semantic theory $ST$ for the categorial language $L$. Taking into account the bi-level semantics of $L$, we have already established an important theorem which characterizes the semantic adequacy for this language and states that for any expression-type $e \in S$ of $L$:

$$
\delta(e) = \delta_K(\mu(e)) \in O,
$$

that is, the same object of the reality described by $L$ corresponds to the denotation of any meaningful expression-type $e$ of $L$ and the denotation of its counterpart which is a constituent of knowledge (see Diagram 2). Semantic language adequacy, like certain intensional and extensional agreement with reality described by the language, is the starting point in the consideration of various aspects of language adequacy.

In compliance with the understanding of the adequacy of language syntax and semantics provided by Frege (1879, 1892), Husserl (1900–1901), Leśniewski (1929, 1930) and Suszko (1958, 1960, 1964, 1968), language adequacy assumes, primarily, that the categories of language expressions – syntactic and semantic (extensional), with the same indices – should be the same. Extending this agreement onto the identity of all distinguished kinds of categories of meaningful expression-types of $L$: syntactic, semantic extensional, as well as semantic intensional, with the same categorial indices, we will use the term categorial adequacy. In order to determine it, we postulate the following:

POSTULATE (categorial adequacy)

$$
SC_\xi = Int_\xi = Eks_\xi, \quad \text{for any } \xi \in I,
$$

where $SC_\xi = \{ e \in S : i_S(e) = \xi \}$.\(^{16}\)

We can formulate the postulate of categorial language adequacy given above in two equivalent ways imposed by conditions a and b of the following theorem (see Diagram 3):
Diagram 3. Categorial adequacy

THEOREM 7 (categorial adequacy)

a. \( e \in SC_\xi \) iff \( \mu(e) \in K_\xi \) iff \( \sigma(e) \in O_\xi \), for any \( e \in S \).

b. \( i_S(e) = i_K(\mu(e)) = i_O(\sigma(e)) \), for any \( e \in S \).

The categorial adequacy is therefore ensured by the identity of categorial indices: of any meaningful expression-type of \( L \), its meaning and its denotation.

There follow from Theorem 7 of categorial adequacy theorem-equivalents of the theorem \((Rf)\), permitting one to state that it is not only a functor and its index, but also the semantic equivalents of the functor – its meaning and its denotation – that can be treated as set-theoretical functions (see Wybraniec-Skardowska, 2009):

THEOREM 8 (meaning and denotation of functor)

If \( e = f(e_1, e_2, \ldots, e_n) \) is a meaningful expression of the set \( S \), satisfying the formula \((i_f)\), then the following equivalences are satisfied:

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\(\begin{align*}
(R2) & \quad \mu(f) \in Ka/\alpha_1 \alpha_2 \ldots \alpha_n \text{ iff} \\
(\mu(f)) & \quad \mu(f) : Ka_1 \times Ka_2 \times \ldots Ka_n \rightarrow Ka \land \\
(PCM) & \quad \mu(e) = \mu((f(e_1, e_2, \ldots, e_n))) = \mu(f)(\mu(e_1), \mu(e_2), \ldots, \mu(e_n)) \\
\end{align*}\)

We call the condition (PCM) the \textit{semantic principle of compositionality of meaning}, and the condition (PCD) the \textit{semantic principle of compositionality of denotation}. These principles were already known to Frege (1892).\(^{17}\)

Loosely speaking, these principles state, respectively, that:

The meaning (resp. denotation) of a well-formed functor-argument expression of \(L\) is the value of the function of meaning (resp. denotation function) of its main functor, defined by meanings (resp. by denotations) of arguments of this functor.

The categorial character of the language \(L\) under consideration allows speaking also about \textit{structural adequacy} as an agreement of the structure of any expression composed of a functor and its arguments, with the structure of the constituent of knowledge that corresponds to it and with the structure of the object of the cognized reality that corresponds to it. \textit{Structural adequacy} is obtained through holding three \textit{principles of compositionality}:\(^{18}\) one syntactic – the principle (PCS) of compositionality of syntactic forms – and two semantic principles: (PCM) and (PCD), of compositionality of meaning and compositionality of denotation.\(^{19}\)

The three principles of compositionality mentioned above, for \(h = is, \mu, \sigma\) and any meaningful expression \(e = f(e_1, e_2, \ldots, e_n)\), have the following common schema:

\[h(e) = h(f(e_1, e_2, \ldots, e_n)) = h(f)(h(e_1), h(e_2), \ldots, h(e_n))\]

which can be treated as a schema of three conditions of the homomorphism of partial algebra \(L\) of \(L\) in the algebra of its images \(h(L)\), i.e.,

\[L = \langle S, F \rangle \xrightarrow{h} h(L) = \langle h(S), h(F) \rangle\]

where \(F\) is a set of partial functor-functions defined by subsets of the set \(S\) and with values in the set \(S\), and \(h(F)\), for \(h = is, \mu, \sigma\), is a set of operations corresponding to operations of the set \(F\).\(^{20}\)
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We call the algebra

\[ i_S(L) = \langle i_S(S), i_S(F) \rangle \]

a syntactic model of \( L \), and the algebras:

\[ \mu(L) = \langle \mu(S), \mu(F) \rangle = \langle K, \mu(F) \rangle \]
\[ \sigma(L) = \langle \sigma(S), \sigma(F) \rangle = \langle O, \sigma(F) \rangle \]

the semantic models of this language; the first is called the intensional model; the other – the extensional model.

In the process of cognition of reality, language adequacy also consists in that sentences of language \( L \) should be true in its above mentioned models.

If for \( h = i_S, \mu, \sigma \) it is so that the sentence \( e \) of \( L \) is true in the models \( h(L) \), then we can say that our cognition is true or that there occurs language cognitive adequacy.

The notions of truthfulness in respective models are introduced in the theories \( T \) and \( ST \) by means of three primitive notions \( Th \), satisfying at \( h = i_S, \mu, \sigma \) the axioms:

\[ \emptyset \neq Th \subseteq h(S) \]

and understood intuitively, respectively, as: a singleton composed of the index of true sentences, a set of true judgments, a set of situations that take place (in Frege’s semantics – a singleton composed of the value of truth).

**DEFINITION 11 (truthfulness)**

For \( h = i_S, \mu, \sigma \)

The sentence \( e \) of \( L \) is true in the model \( h(L) \) iff \( h(e) \in Th \).

Language-related knowledge is passed in the process of inter-human communication. The transmitting and proper reception of it are connected with the proper interpretation of language expressions and communication adequacy, based on the agreement of meaning and interpretation of language expressions which mediate in the communication (see Diagram 4). Thus, if the expression-type \( e \) mediates in the communication between its sender and its receiver, then communication adequacy is secured by the condition:

\[ \mu(e) = \iota(e). \]
Let us pay attention to the fact that formal securing of the communication adequacy of \( L \) is based on such a formalization of it that uses the relations \( \text{Use} \) of using expression-types of this language, and therefore also the relation \( \text{use} \) of using its tokens, since in the presented theory \( ST \) the notions of \( \text{meaning} \) and \( \text{interpretation} \) of meaningful expression-types of \( L \) are defined by means of these relations. This fact implies the possibility of formalizing the notion of an inter-human communication act by means of tokens of language expressions and establishing formal conditions of its adequacy (see Wybraniec-Skardowska & Waldmajer, 2009).

5. Summary

- This paper has offered a synthetic framework of the main ideas and theoretical considerations presented in earlier papers of the author, especially those dealing with the syntax and semantics of language characterized categorically:
  - in the spirit of Husserl’s idea of pure grammar (1900–1901),
  - in compliance with the basic assumptions of the theory of syntactic categories of Leśniewski-Ajdukiewicz,
  - according to Frege’s (1892) ontological canons, and also
  - to Bocheński’s (1949) well-known statement: \textit{syntax mirrors ontology}.
- The formal-logical framework of the theory of language syntax outlined in this work is based on Peirce’s (1931–1935) distinction of sign-tokens from
sign-types, on the assumption that expressions of language possess a double ontological nature: they can be physical concrete objects – *tokens* – or ideal abstract beings – *types*, classes of expression-tokens.

- Taking into account, in the theory of syntax, the double ontological character of language objects, as well as – following Pelc (1971, 1979) – the functional approach to the logical analysis of language, allows speaking about two manners of using language expressions. The first of them – applied in acts of inter-human language-based communication – concerns using expression-tokens; the other – using expression-types and determining on what, formally, correct adequate language communication depends. The other way allows also introducing, formally, basic semantic notions: the notion of *meaning* and that of *denotation* of expression-type, differentiating between them basically (similarly as was done by Frege, 1892, and Carnap, 1947), and also using means of logical pragmatics.

- A formal characteristic of semantic notions takes place in the theory of semantics of language, built over this theory of syntax. The formal-logical theory of language which is presented in this paper, is a result of conceptualizing inter-subjective knowledge about language communication in a liberally established time range, as well as a liberally determined area of such communication. The conceptualization includes the bi-level semantics of language: *intensional* and *extensional*. On the first of them, the *intensional* level of theoretical considerations, the notions of *meaning* and *interpretation* are introduced, making reference to the use (Use) of expression-types (through the use of expression-tokens by users of language) and preserving certain intuitions of Wittgenstein (1953) and Ajdukiewicz (1931, 1935), connected with the first of these notions. On the other, the *extensional* level of theoretical considerations, two notions of *denoting* and two notions of *denotation* are introduced. The notions of *denoting* and *denotation* (extension) of expression-types are differentiated from those of *denoting* and *denotation* of their *meanings* (intensions) treated as constituents of knowledge. All these notions are introduced as semantic-pragmatic ones, through referring to the two mentioned ways of using the expressions. This agreement of the two types of *denotation* is referred to as *semantic adequacy*, since it is connected with the bi-level semantics of language described by the theory under discussion in this paper.

- If – according to the ontological canons of Frege and Bocheński – language is to be a linguistic schema of ontological reality, and – at the same time – a tool of its cognition, its syntax should be in agreement with the bi-level semantics corresponding to it. This compliance has been called *language adequacy*, and its occurrence is guaranteed in the formal theory of lan-
guage by accepting the respective postulate (axiom) of categorial adequacy. There follows from it an important condition of structural (compositional) adequacy, connected with the principles of compositionality of meaning and denotation, which were known already to Frege, and also with their syntactic counterpart introduced in papers by the author.

- In the outlined theory of language there are also formally considered other aspects of language adequacy. They are connected with the effectiveness of human cognition and inter-human communication by means of language expressions.

NOTES

1 The paper is an English translation (including slight transformations and complements) of the author’s paper published in Polish in 2010, O adekwacji językowej. In J. Pelc (Ed.), Deskrypcje i prawda, BMS 51 (pp. 275–306). Warszawa: Polskie Towarzystwo Semiotyczne. The main assumptions of this work were presented at the VIIIth Philosophical Congress held in Warsaw on 16 September 2008, in the paper entitled From syntax to bi-level semantics of language. This paper also develops some ideas which were presented in the author’s earlier papers (2007a, b, c) and (2009, 2010). I would like to kindly thank Professor Mieszko Tałasiewicz and Dr. Edward Bryniarski for their critical and valuable comments which contributed to introducing some complements to the first draft of this paper.

2 Independently of Leśniewski, a theory of syntactic category was presented and developed for the needs of the so-called combinatory logics by Curry (1961, 1963). A somewhat complementary theory to ST is the so-called Transparent Intensional Logic presented by Duzi, Jaspersen and Materna (2010).

3 Let us pay attention in this place to the fact that the notions of intension and extension introduced in the theory ST differ considerably from those introduced in Montague’s pragmatics (1970b).

4 In order to distinguish signs in such a way, Carnap (1942) applies the terms “sign-event” and “sign-disign”.

5 The theory T can be, in an equivalent way, formalized – first – on the level of types, and then – on the level of tokens (see Wybraniec-Skardowska, 1989, 1991, Final Remarks), representing the Platonizing approach to the description of language syntax.

6 In the literature dealing with categorial grammars, it is accepted to refer to the categorial indices introduced by Ajdukiewicz as types. The categorial indices should not, obviously, be mistaken for the indices introduced by Montague (1970b) and applied as the ordered tuples of agent’s factors which constitute the context of usage of expressions.

7 Since, from the pragmatic point of view, equiform tokens may not be identifiable: equiform expression-tokens can have different functor-argument structures, then are treated as different language expressions of language. Thus, types of equiform expression-tokens do not have to be equal.

8 The convergence between Ajdukiewicz’s ideas and those of Husserl regarding the question of meaning of expressions as a manner of their usage is drawn attention to by Olech (2001). The very concept of meaning, deriving from Ajdukiewicz, is discussed in the book by Wójcicki (1999). A review of different concepts of meaning and a discussion on Ajdukiewicz’s concept can be found, among others, in Maciaszek’s copious monograph (2008).
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9 The way in which the expression: \( \text{use}(u,e) = o \) is read cannot be mistaken with the manner of interpreting this expression, in agreement with an intuitive, broad understanding of the operation \( \text{use} \).

10 In English, some not meaningful expressions are, for instance, sentences (well-formed expressions) like the following: \textit{The computer gives the ceiling} or \textit{The flowers are cooking dinner}.

11 Relation \( \equiv i \) is defined by means of the binary relation \( \text{Int} \) of interpreting expression-types (corresponding to the relation \( \text{Use} \)) and the binary operation \( \text{int} \) of interpreting wfe-tokens, about which it is assumed axiomatically that it is a non-empty reduction of the operation \( \text{use} \) of using expression-tokens (see Wybraniec-Skardowska, 2007a, 2007b). The set \( S^* \subseteq S \) is the set of all meaningful expression-types that can be Interpreted by Users of \( L \).

12 Let us pay attention to the fact that – according to the assumptions of the theory \( ST \) – the notion of a \textit{denotate}, as an object of the set \( \text{Ont} \) denoted by an expression-type, is broader than the notion of a \textit{designate of such an expression}, usually accepted in the logic of language. In particular, it is accepted in logical semiotics that \textit{designates} of the so-called concrete names can be material objects only. Such objects can be \textit{denotates} of such names then, but they do not have to be; they can also be intentional, fictional objects. This explains, in particular, certain misunderstandings connected with so-called empty names. Such names as for instance, “Zeus”, “Sphinx” or “Smurf” are acknowledged – on the one hand – to be \textit{empty names} (as ones which do not denote any \textit{designate}), on the other one – as \textit{non-empty names} (as ones denoting their \textit{denotates}).

13 The formal definition of an ambiguous expression-type was given in the author’s earlier paper (2007a).

14 The \textit{global denotation} can also be seen as the upper approximation of denotation of a vague expression, yet in this paper the problem of vageness of language expressions will not be dealt with.

15 See also Stanosz and Nowaczyk (1976).

16 Let us notice that a formalization of the notion of categorial adequacy does not require assuming that language expressions have to have a functor-argument structure. So if language is generated by another type of grammar than a categorial grammar, e.g. a phrase structure grammar or a dependency grammar (see Tensière, 1959), then the postulate could be adapted.

17 See also Gamut (1991).

18 See Wybraniec-Skardowska (2001b, 2010).


20 Ideas connected with the algebraization of language can be found already in works by Leibniz. The algebraic approach to the syntax and the semantics of language can also be found in the works of Dutch logicians of language, especially in those by van Benthem (1980, 1981, 1984, 1986). However, the algebraic approach presented here differs significantly from that given by van Benthem.

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