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ON SEMANTICS AND SYNTAX OF THE BSDT PRIMARY LANGUAGE

Petro Gopych

***Abstract**: Within the binary signal detection theory (BSDT) the semantics and syntax of a primary language (PL, a mathematical framework for internal brain computations) have been proposed and described in a semi-formal form. On the basis of BSDT infinity hypothesis (the infinity of common in the past prehistory of universe, life, and mind), basic BSDT PL notions have been defined. Among them the names of real-world things, their meanings/contexts (they are infinite and common in the past binary strings), meaning complexity, truth, and understanding the truth. Given their infinite contexts BSDT PL names are finite-in-length binary strings that may simultaneously be interpreted as Gödel numbers or uncomputable halting probabilities (fractions of Chaitin's Ω) for binary string algorithms running on particular self-delimiting computers. BSDT PL meaning complexity is compared with Shannon entropy/information, Kolmogorov/algorithmic complexity, Gell-Mann and Lloyd's effective complexity and total information; BSDT PL truth is compared with Tarskian truth. High biological plausibility of the BSDT PL, its potential for disigning the languages with capacities at the level of human natural languages, applications to practical semantic computations and testable empirical predictions are discussed. Because of its infinity hypothesis, BSDT PL is beyond the scope of traditional axiomatic approach to logic and mathematics.*

***Keywords**: meaning, complexity, truth, symbolic communications, semantic computations.*

***ACM Classification Keywords**: C.3 Special-purpose and Application-based Systems; E.4 Coding and Information Theory; F.1.3 Complexity Measures and Classes; H.1.1 Systems and Information Theory; I.2.0 General, I.2.4 Knowledge Representation Formalisms and Methods; J.4 Social and Behavioral Sciences*

1. Introduction

Since Frege [Frege, 1892] the problem of meaning or reference has been regarded as the cental problem in investigations of language. At the same time, it is supposed 'we will not get an adequate theory of linguistic reference until we can show such a theory is part of the general theory … of how the mind is related to objects in the world in general' [Searle, 1981; p. xi]. Recent binary signal detection theory (BSDT [Gopych, 2008a]) and its atom of consciousness model (AOCM [Gopych, 2009b]) provide the background for the theory requiered. On this basis a possibility arises to find a new solution to the problem of meaning/interpretation – the main focus of semantics. In this paper such a solution is proposed using the BSDT version of a low-level or 'primary language *truly* used by the cental nervous system' and structurally 'essentially different from those languages to which our common experience refers' [von Neumann, 1958; p. 92].

BSDT primary language (PL) gives a common mathematical framework for the description of brain spiking activity involved in signal processing, memory storage/retrieval, decision-making [Gopych, 2008b], and consciousness [Gopych, 2009b]. It is supposed it has to be sufficient to maintain the basic/principal/involuntary behavioral tasks that do not require for their support any additionally elaborated symbolic interanimal communication systems. It may also serve as a ground for a 'bottom-up' description and design of more complicate symbolic systems, including human natural/public/ordinal word languages, used by animals/humans for their social interactions.

2. BSDT PL Vocabulary, Infinity Hypothesis

The BSDT operates with i-dimensional spinlike (with components ±1) binary vectors $x^{(i)}$ constituting a binary vector space, S_{xi} [Gopych, 2009a]. They may also be considered as i-bit strings or elements/points of the set, S_{xi}, whose cardinality (the number of elements) is $|S_{xi}| = 2^i$. If there are string variables $x^{(p)}$, with values ranged in S_{xp}, and $x^{(q)}$, with values ranged in S_{xq}, then $x^{(i)} = x^{(pq)} = x^{(p)}x^{(q)}$, with values ranged in $S_{xi} = S_{xpq}$, can be treated as 'compound' variables; $|S_{xi}| = 2^i$, $i = p + q$; if $p \leq q$, $S_{xp} \subseteq S_{xq}$. The space S_{xi} may also be interpreted as either the S_{xp} whose vectors are colored in 2^q colors or the S_{xq} whose vectors are colored in 2^p colors. If so, p and q are the measures of discrete ('colored') nonlocalities ('rainbows') of points/vectors in spaces S_{xq} and S_{xp}, respectively.

Two-color nonlocality for coding/decoding of noised binary signals was earlier analyzed in [Gopych, 2009a]. By induction it can be demonstrated that vectors related to any number of such spaces can similar be combined (see Fig. 1). For compound strings, communicative and associative laws are valid, namely $x^{(pq)} = x^{(qp)}$, $x^{(pqr)} = x^{(pq)}x^{(r)} = x^{(p)}x^{(qr)}$, etc. BSDT vectors/strings just introduced can be thought of as *words* or names/terms of BSDT *primary language* (PL). They constitute its *vocabulary* written using the PL *alphabet*: '+1', '−1', usual signs of arithmetics, and some auxiliary simbols.

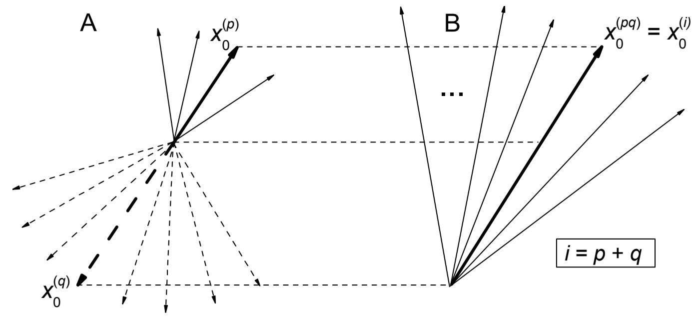

Figure 1. The scheme of designing a compound space, $S_{xpq} = S_{xi}$. **A**, Spaces S_{xp} and S_{xq}, the constituents of S_{xi}; string variables $x^{(p)}$ ranged in S_{xp} and $x^{(q)}$ ranged in S_{xq} are respectively shown as solid and dashed arrows (p = 2, q = 3); particular values of $x^{(p)}$, $x_0^{(p)}$, and $x^{(q)}$, $x_0^{(q)}$, are highlighted in bold; the set of dashed arrows desplays the 'rainbow' of $|S_{xq}| = 2^q = 8$ 'colors' that may color each of the solid arrows (2^q-nonlocality of vectors in S_{xp}), or analogously for dashed arrows (2^p-nonlocality of vectors in S_{xq}). **B**, Compound space S_{xi} (it is uncolored, i = 5, $|S_{xi}| = 2^i = 32$) ; variables $x^{(i)}$ ranged in S_{xi} are shown as in **A** (a part of them is only presented); particular $x^{(i)} = x_0^{(i)}$ is highlighted in bold. Horizontal dashed lines point to relations between the lengths of $x_0^{(p)}$, $x_0^{(q)}$, and $x_0^{(i)}$.

Let c_{x0} be a one-side infinite (infinite 'in the past', at the beginning) spinlike binary string of the length $l(c_{x0})$. If c_{x0} is arbitrary disjointed into two parts, we get $c_{x0} = c_{xp}x_0^{(p)}$ where c_{xp} is again infinite in the past string while $x_0^{(p)}$ is a finite string of the length $l(x_0^{(p)}) = p$. Then the length of c_{xp} equals $l(c_{xp}) = l(c_{x0}) - p$. We say that compound string $c_{x0} = c_{xp}x_0^{(p)}$ is a value of (or bound condition for) the string form $c_{xp}x^{(p)}$ with c_{xp} as a string constant and $x^{(p)}$ as a string variable ranged in S_{xp}. This form provides $|S_{xp}|$ compound strings of the length $l(c_{x0})$ that share their infinite initial part, c_{xp}, prefixed by different values of $x^{(p)}$. If c_{x0} is disjointed into two parts in another way, e.g. $c_{x0} = c_{xq}x_0^{(q)}$, then we similary obtain the form $c_{xq}x^{(q)}$ where c_{xq} is an infinite string constant of the length $l(c_{xq}) = l(c_{x0}) - q$ and $x^{(q)}$ is a string variable of the length $l(x^{(q)}) = q$ ranged in S_{xq}. The number of compound strings of the length $l(c_{x0})$ shared infinite initial part c_{xq} that is prefixed by different values of $x^{(q)}$ is $|S_{xq}|$. Since c_{xp}, c_{xq}, c_{x0} share their infinite initial parts and c_{xp} and c_{xq} are prefixed given the length of c_{x0} by prefixes of different non-zero lengths, $p \neq q$, either c_{xp} is longer than c_{xq} by abs($p - q$) bits or vice versa (Fig. 2A). Hence, for the above reasons and under above conditions, in spite of one-side infinity of c_{x0}, c_{xp}, and c_{xq}, their lengths can explicitly be compared. That is the BSDT *infinity hypothesis* which is rather well empirically supported and reflects the unity of universe, life, and mind [Gopych, 2009a]. (Note, the number of ways the c_{x0} can be disjoined into two parts is the length of c_{x0} in bits, $l(c_{x0})$, or the first Cantor's infinite cardinal number.)

The above consideration can be generalized by assuming the existence of a set, S_{cx0}, of all possible infinite and common in the past compound strings $c_{xi}x_j^{(i)}$ of the length $l(c_{x0})$. Here, c_{xi} is infinite in the past string of the length $l(c_{xi})$, $x_j^{(i)}$ is its jth prefix of the length i, and the (bounded) condition $l(c_{x0}) = l(c_{xi}) + i$ holds. Index i = 0, 1, 2, … specifies the ways of dividing the c_{x0} or generating the c_{xi} (if c_{x0} remains intact, i = 0, $c_{xi} = c_{x0}$); index j = 1, 2, 3, …, 2^i specifies the jth value of string variable $x^{(i)}$, $x_j^{(i)}$. Mentioned above strings $x_0^{(p)}$, $x_0^{(q)}$, $x_0^{(i)}$ are examples of values $x_j^{(p)}$, $x_j^{(q)}$, $x_j^{(i)}$. Every $c_{xi}x_j^{(i)}$ related to the S_{cx0}, $c_{xi}x_j^{(i)} \in S_{cx0}$, is uniquely labeled by decimal indices i and j or by the string $x_j^{(i)}$ (it encodes i and j in binary notations as its length and its content, or particular arrangement of its positive and negative components; prefixes/names $x_j^{(i)}$ provide actually *Gödel numbering* of strings $c_{xi}x_j^{(i)}$, the members of S_{cx0}; i.e., the names themselves are their Gödel numbers, $G^x_{ij} = x_j^{(i)}$). The S_{cx0} is a set/class that is a member of nothing (a so-called proper or ultimate class [Quine, 1969]), its cardinality is infinite but countable. Thus, BSDT PL is in general a transfinite language: though its vocabulary is limited at any moment, it may by request arbitrary be enlarged to the extent constrained mainly by animal's morphology only.

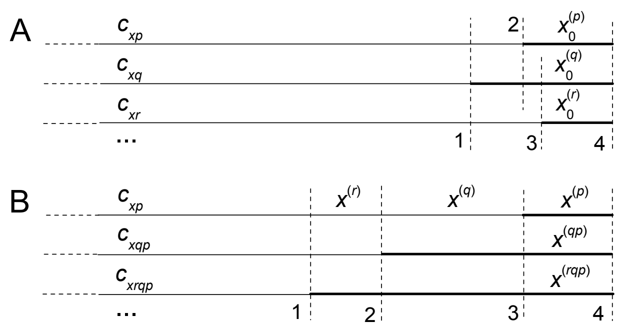

Figure 2. Explaing the BSDT infinity hypothesis. **A**, Dividing the c_{x0} into two parts; infinite in the past strings c_{xp}, c_{xq}, c_{xr}, thing lines that are the same from their beginning to vertical dashed line 1; prefixes $x_0^{(p)}$, $x_0^{(q)}$, $x_0^{(r)}$, thick line segments of lengths p, q, r (they are the values of string variables $x^{(p)}$, $x^{(q)}$, $x^{(r)}$); relations between the lengths of c_{xp} and c_{xq}, c_{xq} and c_{xr}, c_{xr} and c_{xp} are as follows: $l(c_{xp}) - l(c_{xq}) = -(p - q) > 0$, $l(c_{xq}) - l(c_{xr}) = -(q - r) < 0$, $l(c_{xr}) - l(c_{xp}) = -(r - p) > 0$ (cf. distances between dashed lines 1 and 2, 1 and 3, 2 and 3). **B**, Graphical presentation of string categories; string variables $x^{(p)}$, $x^{(q)}$, $x^{(r)}$ (distances between dashed lines 3 and 4, 2 and 3, 1 and 2) are constituents for compound variables $x^{(qp)}$, $x^{(rqp)}$ (distances between dashed lines 2 and 4, 1 and 4); c_{xp}, c_{xqp}, c_{xrqp} are infinite contexts (thing lines) for variables $x^{(p)}$, $x^{(qp)}$, $x^{(rqp)}$ (thick lines of lengths p, $q + p$, $r + q + p$). If to replace strings $x_0^{(p)}$, $x_0^{(q)}$, $x_0^{(r)}$ by string variables $x^{(p)}$, $x^{(q)}$, $x^{(r)}$ then lines in **A** represent respective string categories shown in **B**. The string c_{x0} (or Chaitin's Ω [Chaitin, 1998], horizontal lines) begins infinitely far 'in the past' (dashed segments on the left) and ends 'at the present' (vertical dashed lines 4).

3. BSDT PL Meaning Functions

For $c_{xi}x_j^{(i)}$, $x_j^{(i)}$ is the string's unique but meaningless *name*; c_{xi} is the name's infinite in the past *context*; the name's *meaning* that an animal has *actually* in mind is $M(x_j^{(i)}) = c_{xi}x_j^{(i)}$. It is defined by both the name's context, c_{xi}, and the name itself, $x_j^{(i)}$. We refer to an $M(x_j^{(i)})$, $M(x_j^{(i)}) \in S_{cx0}$, as a BSDT *meaning* or *mind function* given context, c_{xi}; the $M(x_j^{(i)})$ transforms the names from their meaningless, $x_j^{(i)}$, to their meaningful, $c_{xi}x_j^{(i)}$, form. The length of the $M(x_j^{(i)})$ in bits, $l(M(x_j^{(i)}))$, is thought of as the name's *meaning complexity* (Sect. 5).

The context, c_{xi}, is usually shared by a set/range of names, $x_j^{(i)}$, that are the values of string variable $x^{(i)}$. We say that $C(x^{(i)}) = c_{xi}x^{(i)}$ is given the c_{xi} a *category/concept/notion/class* of names $x_j^{(i)}$ or values of $x^{(i)}$, $x_j^{(i)} \in S_{xi}$ and $|S_{xi}| = 2^i$. The i is *ensemble complexity*[1] of the $C(x^{(i)})$ *given* its context, c_{xi}. Hence, the complexities of different categories may only be compared if they share the same context. The set of $|S_{xi}|$ of names $x_j^{(i)}$ constitute given the c_{xi} the set of the category's *synonyms*/features/attributes/traits/properties. Thus, a synonymy (and an interchangeability of synonyms in their following use) takes place only among the members, $x_j^{(i)}$, of the same category of names, $C(x^{(i)})$. That is the BSDT PL's semantic *rule of identity* or an explication of its identity sign/connective '='.

When particular real-world thing/object/event related to the $C(x^{(i)})$ is named, each the category's item is only specified by the value $x_j^{(i)}$ of string variable $x^{(i)}$ or, in other words, by the name's content only – a *randomly* chosen arrangement of its i positive and negative components. (Here the rigidity and accidantelity of names/designations usually treated as different notions, e.g. [Kripke1990, p. 60], are reconciled.) To name the $C(x^{(i)})$ given the c_{xi},

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[1] It is like information or entropy [Shannon, 1948] for the $C(x^{(i)})$ given c_{xi}, $H(C(x^{(i)})) = H(x^{(i)})$. The category $C(x^{(i)})$ has $|S_{xi}| = 2^i$ synonyms/states, the probability of occuring of each of them is $P(x_j^{(i)}) = 1/|S_{xi}|$. Shannon's information/entropy/complexity is $H(x^{(i)}) = -\sum(\log_2 P(x_j^{(i)}))/|S_{xi}| = i$ bits; $j = 1, 2, \ldots, 2^i$.

suffice it to fix the i. Then the value of i, if it is written as a string, $u_s^{(r)}$, is the *name of the category*.[1] Indeed, knowing the i, $|S_{xi}|$ of names constituting the category can be specified by their contents or, what is the same, by the ordinals[2] 1 to $|S_{xi}|$ in binary string notations. The category's constituent names, $x_j^{(i)}$, are given context nothing more than the ordinal (natural) numbers with their upper limit $|S_{xi}|$. In other words, any category as a whole, $C(x^{(i)})$, can completely be specified by its context, c_{xi}, and by either all the constituting it synonyms (the values of $x^{(i)}$ ranged in S_{xi}) or the category's unique name, $u_s^{(r)}$. The meaning of the category's name is defined by both the name itself, $u_s^{(r)}$, and the name's context, c_{ur}, i.e. $M(u_s^{(r)}) = c_{ur}u_s^{(r)}$ under condition $c_{xi} = c_{ur}$.

Meanings $M(u_s^{(r)})$, $M(u_s^{(r)}) \in S_{cu0}$, and $M(x_j^{(i)})$, $M(x_j^{(i)}) \in S_{cx0}$, are members of sets S_{cu0} and S_{cx0} that comprise the strings that share their infinite initial part but differ in length, by $i - r$ bits (prefixes $u_s^{(r)}$ and $x_j^{(i)}$ provide Gödel numbering of members of S_{cu0} and S_{cx0}, respectively). Names $x_j^{(i)}$ and $u_s^{(r)}$ are of different levels[2] and denote things of similar but different nature (with mostly common but different in length evo-devo prehistories, see below). Strings $M(u_s^{(r)}) = c_{ur}u_s^{(r)}$ may be treated as fractions of strings $M(x_j^{(i)}) = c_{xi}x_j^{(i)}$ if strings $u_s^{(r)}$ are treated as *fringe* (left-most in Fig. 2B and Sect. 4) fractions of compound strings $x_j^{(i)}$. In such cases, the meaning of $x_j^{(i)}$ is precise and clear while the meaning of $u_s^{(r)}$ is vague. Where $u_s^{(r)}$ is treated as a fringe of $x_j^{(i)}$, the vagueness of meaning of the $u_s^{(r)}$ is measured by its colored $2^{(i-r)}$-nonlocality (Sect. 2). Thus, in just described 'fuzzy' or 'vague' sense only, it may be that $S_{cu0} \subseteq S_{cx0}$ and meanings $c_{xi}x_j^{(i)}$ and $c_{ur}u_s^{(r)}$ are related given the $c_{xi} = c_{ur}$.

Given the c_{xi} strings $x_j^{(i)}$ are perfect for most profitable, concise (the best, incompressible) binary coding of distinctions in naming the category's items. Keeping the sum, $l(c_{x0}) = l(c_{xi}) + i$, but varing the length of $x_j^{(i)}$, i, an infinite series of infinite and common in the past strings $c_{xi}x_j^{(i)}$, with different in length right-most *random-valued* fractions $x_j^{(i)}$, can be obtained in a way when each longer $x_j^{(i)}$ contains as its right-most part any shorter one. Such infinite strings, $c_{xi}x_j^{(i)} \in S_{cx0}$, are by definition [Chaitin, 1998] *random* and *uncomputable*.

Among infinite binary strings with definite but uncomputable (random) components, it is selected the one, Ω [Chaitin, 1998], that given computer (its hardware and software) provides halting probabilities for algorithms of any length; namely i right-most bits of Ω, Ω_i, give halting probabilities for algorithms not longer than i. Hence, any $c_{xi}x_j^{(i)} \in S_{cx0}$ can be interpreted as the Ω whose the ijth right-most fraction of i bits, Ω^x_{ij}, is specified given the ijth randomly chosen self-delimiting computer. Moreover, random strings $x_j^{(i)}$ can be treated [Chaitin, 1998] as true, unprovable assertions or irreducible mathematical facts that can only be deduced by adding them as axioms. The $|S_{cx0}|$ provides the amount of different possible finitely defined computers self-delimiting by respective values of i. Since meaning functions are the items of S_{cx0}, $M(x_j^{(i)}) \in S_{cx0}$, they are also random and uncomputable, and their arguments, $x_j^{(i)}$, are, given the ijth computer, the ijth fractions of Ω, $\Omega^x_{ij} = x_j^{(i)}$; the properties of c_{xi}, except its property of being infinitely long and common in the past for different $x_j^{(i)}$, are here not essential in general.

Each string $x_j^{(i)}$ is selected by its BSDT abstract selectional machine, ASM($x_j^{(i)}$) [Gopych, 2007], designed beforehand to do this. Explicit meaning of $x_j^{(i)}$ is presented as infinite-in-length *symbolically written* complete evo-devo (evolutionary and developmental) prehistory, $c_{xi}x_j^{(i)}$, of designing the real-world ASM($x_j^{(i)}$). Since an animal's real-world *physical* ASM($x_j^{(i)}$), i.e. implicit meaning of $x_j^{(i)}$, is in turn the ijth network internal ('mental') representation of the jth internal/external object/event [Gopych, 2008b, 2009b], the meaning of $x_j^{(i)}$ depends on the current animal state and animal relations to the environment. In that sense, the name's meaning is just the

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[1] The name $u_s^{(r)}$ is the sth value of binary string variable $u^{(r)}$ or a vector of the dimension r. The r equals either $\log_2(N_{xi})$ if it is a natural number or $[\log_2(N_{xi})] + 1$ in opposite case, […] means a part of a real number before its decimal point and $i > 0$; $u_s^{(r)} \in S_{ur}$, $|S_{ur}| = 2^r$; $l(c_{xi}x_j^{(i)}) - l(c_{ur}u_s^{(r)}) = i - r > 0$. Hence, the names $x_j^{(i)}$ are longer (more complex) than the names $u_s^{(r)}$. The form $C(u^{(r)}) = c_{ur}u^{(r)}$ defines, we say, a *higher-level* category whose *higher-level* constituent names, $u_s^{(r)}$, designate given the context, c_{ur}, $|S_{ur}|$ of different *first-level* categories. One of such categories, $C(x^{(i)})$, of *first-level* constituent names, $x_j^{(i)}$, is discussed. Other first-level categories related the $C(u^{(r)})$ and more higher-level categories are here not considered. An infinitely deep hierarchy of property names and related notion names built in such a way may be treated as their BSDT LT *ontology*.

[2] The possibility 'to take the ordinals themselves as primitive terms' was still envisaged in [Gödel, 1946].

animal's being in a certain *psychological* state. (Note, for any binary message $x_j^{(i)}$, its meaning, $M(x_j^{(i)})$, exists in its implicit, $M_{\mathrm{impl}}(x_j^{(i)})$, or explicit, $M_{\mathrm{expl}}(x_j^{(i)})$, form [Gopych, 2009b]. Since this paper is mainly devoted to a *symbolic* lanquage, we are here usually dealing with $M(x_j^{(i)}) = M_{\mathrm{expl}}(x_j^{(i)})$.)

The context c_{xi} gives the description of designing the $C(x^{(i)})$, a category of ASMs selecting the values of $x^{(i)}$, $x_j^{(i)} \in S_{xi}$. Thus, given context the meaning of $C(x^{(i)})$ is $|S_{xi}|$ of real-world physical ASMs, ASM($x_j^{(i)}$) with j from 1 to $|S_{xi}|$, representing respective things. In other words, the meaning of a category of names is eventually a set of real-world objects/events given to an animal *through* its particular psychological state – the state of activity of complex hierarchies (neural subspaces) of typical neural networks constituting a common milieu for signal processing, memory storage/retrieval, decision-making [Gopych, 2008b] and consciousness [Gopych, 2009b]. Resulting meanings are used for animal mental (brain) *meaningful*/*semantic* computations needed for animal adaptive behavior in its natural (including social) environment. This explains why BSDT PL names taken in isolation are actually *meaningless* by themselves: their meanings are mostly in their contexts that can be written as infinite binary strings and implemented as real-world ASM hierarchies (neural subspaces) playing the role of separate computers devoted to serve (to generate the meaning for) respective meaningless names. Hence, the BSDT predicts the following effect. By examining in experiment a given ASM hierarchy that generates the meaning of particular $x_j^{(i)}$, parameters describing the hierarchy itself may successfully be found but the content of $x_j^{(i)}$ – specific arrangement of its components – will always remain unknown (it becomes irrelevant and not essential once the hierarchy in question was picked out for the investigation).

4. Meanings of BSDT PL Compound Names

From the comparing of Fig. 2A and B follows that, for a compound string variable, e.g. $x^{(rqp)} = x^{(r)}x^{(q)}x^{(p)}$, only its right-most constituent, $x^{(p)}$, can correctly be assigned to its context, c_{xp}, and can turn out to be a category of names, $c_{xp}x^{(p)}$, with constituent names $x_j^{(p)}$ ranged in S_{xp}. Other constituents of the $x^{(rqp)}$, though in it they are certainly presented, cannot manifistate their precise meanings and remain to an extent fundamentally vague, opaque, or oblique. We refer to the compound string's right-most variable (category of names, $c_{xp}x^{(p)}$) as a focal one, the other variables (categories) are referred to as its surround or '*fringe*'. One of $|S_{xp}|$ of values of $x^{(p)}$, e.g. $x_0^{(p)}$, can be transformed into the meaningful string, $c_{xp}x_0^{(p)}$, whereas all its other values, $x_j^{(p)} \neq x_0^{(p)}$, are in $x^{(p)}$ and $x^{(rqp)}$ only *implicitly* presented, as available in principle possibilities. The right-most compound constituent of $x^{(rqp)}$, $x^{(qp)} = x^{(q)}x^{(p)}$, can in turn be interpreted as a category of names, $c_{xqp}x^{(qp)}$, with its precisely defined context, c_{xqp}; one of $|S_{xqp}|$ of values of the $x^{(qp)}$, e.g. $x_0^{(qp)}$, can in turn be transformed into a meaningful string $c_{xqp}x_0^{(qp)}$, whereas all its other values, $x_j^{(qp)} \neq x_0^{(qp)}$, are in $x^{(qp)}$ and $x^{(rqp)}$ only implicitly presented. Finally, the compound variable $x^{(rqp)}$ can in itself be presented as a category of names, $c_{xrqp}x^{(rqp)}$, with its precisely defined context, c_{xrqp}; one of $|S_{xrqp}|$ of values of the $x^{(rqp)}$, e.g. $x_0^{(rqp)}$, may in turn be transformed into a meaningful string $c_{xrqp}x_0^{(rqp)}$, whereas all its other values, $x_j^{(rqp)} \neq x_0^{(rqp)}$, are in $x^{(rqp)}$ only implicitly presented. Because of laws of communicativity and associativity, any number of compound string's constituents may be arranged in an arbitrary fashion and creat a compound *sub*string that, as any other compound string's constituent, can take in it the right-most (focal) position. We see, compound string's meaning may be constructed of meanings of its constituents either 'analytically' (taking it serially, 'term by term' [Quine, 1992], as a set of meanings of its constituents) or 'holophrasically' (taking it as 'a seemless whole' [Quine, 1992], not noticing explicitly the meanings of compound string's constituents). In any case, the BSDT PL lacks direct 'compositional semantics'.

Compound names are thought of as BSDT PL *sentences* and, simultaneously, BSDT PL descriptions of BSDT neural subspaces – the neural network hierarchical milieu (cf. Fig. 3 in [Gopych, 2008b] and Fig. 1 in [Gopych, 2009b]) for BSDT signal processing, memory, decision-making and consciousness [Gopych, 2008b, 2009b]. If so, the number of compound name's constituents is also treated as an animal's logical/reasoning deepness [Gopych, 2009b], the value of focal string variable corresponds to memory's feature/attribute that is currently in the focus of attention, the focal variable's fringe is the fringe of animal's memory or consciousness. Compound name's 'holophrasical' presentation describes the perception/remembering of a scene in a whole (diffuse focus of attention), whereas its 'analytical' presentation describes the serial perception/remembering of the scene by its (compound or not) fractions (acute focus of attention). Any paraphrase (rearrangement of constituents) of the BSDT sentence cannot change its meanings as a whole. The combining of BSDT PL names into sentences and operating on them should always be performed *given* their meanings. In that sense BSDT PL semantics (interpretating the names) is primary with respect to its syntax (rules for the construction and transformation of sentences) though they are of course closely interrelated.

5. BSDT PL Meaning Complexity

An $x_j^{(i)}$ becomes meaningful once it is attached to its respective infinite in the past context, c_{xi}, describing the ASM devoted to select the $x_j^{(i)}$, ASM($x_j^{(i)}$) [Gopych, 2007]. For all the first-level names, resulting strings, $M(x_j^{(i)}) = c_{xi}x_j^{(i)}$, have the same total length or *meaning complexity*, $l(c_{xi}x_j^{(i)}) = l(c_{xi}) + i = l(c_{x0})$, reflecting in a sense animal's complexity, *not* the complexities of things the names designate (note, all animal's tissues share their genetic structure). For a higher-level name, $u_s^{(r)}$, its meaning complexity, $l(c_{ur}u_s^{(r)}) = l(c_{ur}) + r = l(c_{u0})$, is described in the same way though it is smaller by $i - r$ bits than meaning complexity, $l(c_{x0})$, of its first-level names, $x^{(i)}$ (footnote 2). Thus, meaning complexities of names of real-world things of any nature or notions of them should simultaneously be specified by *two* kinds of additive complexities: infinite *context complexity*, e.g. $l(c_{xi})$ for given-level meaningless names $x_j^{(i)}$, and their finite *ensemble complexity*, i. Ensemble complexity or Shannon information/ entropy (footnote 1) is defined for a set of $|S_{xi}|$ of names and quantifies average or *ensemble properties* of meaningless names, $x_j^{(i)}$, while the ensemble's *individuality* is quantified by their common context complexity, $l(c_{xi})$. Infinite meaning complexity quantifies the *individuality* or the sameness of (meanings of) either a separate name or a separate category of names (or the sameness of animal's respective psychological states).

A name's meaning complexity or the first Cantor's cardinal number, $l(c_{xi}x_j^{(i)}) = l(c_{x0})$, is infinite but, because of our infinity hypothesis (Sect. 2), comparable with meaning complexities of other names. Any category of compound names, $c_{xqp}x^{(qp)}$, with respect to its constituent categories, $c_{xp}x^{(p)}$ and $c_{xq}x^{(q)}$, has smaller context complexity, i.e. $l(c_{xqp}) < l(c_{xp})$ and $l(c_{xqp}) < l(c_{xq})$, and larger ensemble complexity, i.e. $q + p > p$ and $q + p > q$, whereas their constituent names, no matter whether they are compound or not, have the same meaning complexity, $l(c_{x0})$, and no ensemble complexity (see Fig. 2). In other words, for names of the same level, any association of them cannot change their meanings acquired beforehand or make the compound name more meaningful than its constituents. Only the names of different levels have different meaning complexities.

6. BSDT PL Truths, Communication Paradox

The *ij*th name $x_j^{(i)}$ of the length i is true if its meaning, $M(x_j^{(i)})$, is true or, in other words, strings c_{xi} and $x_j^{(i)}$ (the name's context and the name itself) are correctly adjoined to or satisfy each other. Thus, for all the category's names, $x_j^{(i)} \in S_{xi}$, their meanings, $M(x_j^{(i)}) = c_{xi}x_j^{(i)}$, are to be *consistent* or, in other words, their context string, c_{xi}, has to be the same and the relation $l(c_{xi}) + i = l(c_{x0})$ has to be valid. In opposite case, the *ij*th meaningful name is false. Since the cardinality of S_{cx0}, $|S_{cx0}|$, is infinite, the number of BSDT PL truths (true meaningful names) is infinite in general and, for any such meaningful string, its truth-value (either 'true' or 'false') certaintly exists. At the same time, because compound string's fringe constituents are within it colored due to their discrete nonlocality (Sect. 2), the meanings of fringes are neither true nor false; they are 'in limbo' [Quine, 1992] or fuzzy/vague in meaning. This is a BSDT PL counterpart to Gödel's incompletness theorem (note, particular axioms and theorems for which Gödel's results hold are in our terms an infinite fraction of infinite in number meaningless strings $x_j^{(i)}$). The BSDT PL truths are here introduced as a correspodence between names and reality. All the meaningful names, e.g. $c_{xi}x_j^{(i)} \in S_{cx0}$, are by definition true because they name particular real-world things given to an animal through its respective psychological states. Thus, for the BSDT PL, the truth is a norm and the falsity is an anomaly caused, e.g., by animal's disfunction or disease. In any case, there is *no* lie and *no* liar paradox, a severe problem of formal logic, e.g. [Quine, 1992], and a source of the Gödel's incompleteness which does not hold for BSDT PL *meaningful* names, $c_{xi}x_j^{(i)}$. This inference is caused by the fact that BSDT PL name meanings are the ones that animals/humans have actually in mind and are mainly concentrated in their infinite contexts.

Since complete symbolic meaningful descriptions of BSDT PL names, $c_{xi}x_j^{(i)}$, are fundamentally *infinite*, they cannot be communicated even in principle. To solve this *communication paradox* [Gopych, 2009b], we appeal to our infinity hypothesis. Let an ASM-sender and an ASM-receiver share their prehistory/context, i.e. let they were designed beforehand to perform the same meaningful function – selecting a finite-in-length symbolic message, $x_j^{(i)}$, given its infinie context, c_{xi}. Only in such a case the meaning of $x_j^{(i)}$, $c_{xi}x_j^{(i)}$, is equally coded/decoded/ interpreted or, in other words, equally *understood* by both parties. For this reason, and because the name's meaning is the psychological state an animal experiences when it produces or perceives the name (see Sect. 3), in meaningful information exchange, both the sender and the receiver are to be *physically* and *functionally* equivalent. Thus, correct understanding of meanings of different names is only possible if the numbers of ASM-senders, of ASM-receivers and of names to be produced/received by particular animal are equal to each other. Of this follows that the paradigm of network coding/decoding of meaningful messages should be 'one-memory-trace-per-one-network', the rule actually employed by the BSDT [Gopych, 2008b]. According to recent empirical neuroscience findings (discovering the coding by 'synapse assemblies' [Xu, 2009; Yang, 2009]), the same coding/decoding rule is also to be used by animals. Since ASM prehistories include complete stories of ASM *individual* development, completely equivalent ASMs/ASM hierarchies are practically impossible. For this reason, meaning understanding is always either to some extent vague or even wrong in worse cases. The sameness of ASM contexts is here the key. An animal involuntary demonstrates its actual internal psychological states (meanings of respective BSDT PL names, Sect. 3) by its basic/principal/involuntary behaviors. Another animal of the same species watching the first one would be able to understand it, because they the both have similar bodies and nerve systems (i.e. the same morphology produced by their common evo-devo prehistories) and would similar behave in similar environmental situations. For animals, to understand each other's behavior means to match the activities of respective parts of their nerve systems (neural subspaces or ASM hierarchies representing the respective names) no matter whether particular animal behaves or only watches the behavior of others. This BSDT PL prediction is completely consistent with well known neuroscience finding of 'mirror' neurons – the ones that are active in motor brain areas of animals that are only watching respective motor behavior of others, e.g. [Rizzolatti, 2004]. For meaningful interanimal behavioral information exchange (involutanary understanding of each other's basic behaviors), there is no need in any specially developed additional symbolic communication system (language). It may only be required *to enrich* animal's basic communication faculties.

The truth values as such are together with names never communicated. They should always be discovered and confirmed by checking the correspondence of names to the reality or, more directly, to animal's respective psychological states. Most probably it is doing by physical/anatomical segregation and specification of communication channals (input/output sensory submodalities) or carriers for communication signals, with the following convergence of relevant channel-specific information. By means of such segregation and specification, particular neural subspaces/ASM hierarchies (or computers for particular mental computations, Sect. 3) are eventually allocated. By the convergence of information from different communication channels, an integral and, consequently, most reliable estimation of the current state of animal's environment has to be achieved.

7. Some BSDT PL Applications

The semantics proposed generates a manual for practical semantic computations. On the one hand, it is surprisingly simple because it recommends *to have* before the beginning of computations on names $x_j^{(i)}$ their already known infinite contexts, c_{xi}, i.e. to use already completely established formal models of reality. Numerous computations in mathematical physics, chemistry, biolology, etc could be considered as approximate examples. On the other hand, it is surprisinly complex because it recommends *to perform* beforehand complete symbolic descriptions of infinite contexts, c_{xi}. This goal can of course never be achieved. That is, the main problem of symbolic semantic computations is the incompleteness of contexts or, in other words, 'mathematical' models of reality. Once they became known (at least approximately), BSDT PL semantic computations are reduced to usual Turing-machine operations on strings $x_j^{(i)}$ and could easily be performed, e.g. [Gopych, 2006, 2008b].

BSDT decoding algorithms [Gopych, 2008a, 2008b] serve as BSDT PL rules of inference. They are conventional operations on binary vectors $x_j^{(i)}$, can be presented as ASMs [Gopych, 2007] and exist in neural network, convolutional and Hamming distance forms that are functionally equivalent and the best [Gopych, 2008a]. To be able to be meaningful, each message $x_j^{(i)}$ is stored and processed by its separate ASM. At the same time, the BSDT PL says nothing of mechanisms of arrangement/rearrangement of its compound names (sentences) and of selecting their those fragments that are to be placed into the current focus of attention (see Fig. 2B). For this reason, an appeal to a kind of analog (e.g. wave-like) computations seems to be inavoidable (see also [Gopych, 2009a]). An animal's morphology is also essential for verifying the truth-values of names to be communicated. Thus, the BSDT PL as such is *incomplete* and, consequently, *insufficient* to ensure its own running in full.

One of distinctive features of the BSDT PL is that its names are in the norm true (Sect. 6). That is why it is so well to serve as primary language for maintaing an animal's ongoing internal activity. For the same reason, it can serve as a 'source language' whose names (animal's respective psychological states) may next be translated into vocal, gestical, etc tokens of a more elaborate symbolic communication system needed to support information exchange between animals of a group. The more complicate the group's sociality, the more complicate communication system is required to support it (and vice versa). Since among other animals humans do have most complicate sociality, human natural languages are to be most complicate and elaborate. The BSDT PL may be used for the construction of such 'secondary' [von Neumann, 1958] languages whose capacities may be at the level of human natural languages. If so, semantics and syntax of natural languages should be in a broad sense the functions of semantics and syntax of the BSDT PL. Specific form of these fuctions should be defined by mechanisms of (and innate brain structures for) the translation of the primary language into a secondary one. In that sense the BSDT PL is a precursor for or a counterpart to so-called 'universal grammars', e.g. [Chomsky, 1997]. The BSDT PL is a universal language for communicating the meanings of its words/names or animal's respective psychological states by means of animal's basic/involuntary behaviors that could represent the behavioristic part of its more complex adaptive behaviors. For animals of the same and, in many cases, of different species, thanks to their mirror neurons [Risolatti, 2004], it is intelligable without any effors. For animals with most primitive sociality or for their *artificial* counterparts, a version of the BSDT PL may serve as an *exhaustive* (though *incomplete*, see above) set of tools for their routine communications.

8. Discussion

Perhaps most important tenet of the BSDT PL is its *infinity hypothesis* – the idea that BSDT contexts specifying the symbolic descriptions of meanings of names are infinite 'in the past' binary strings sharing their infinite initial part (Sect. 2). It is grounded on to date rather established natural phenomenon of the unity (common coevolution) of universe, life, and mind [Gopych, 2009b] and further elaborates, e.g., famous Zermelo's infinity axiom, e.g. [Quine, 1969]. Armed with its infinity hypothesis, the BSDT PL becomes the theory spreading *beyond* the scope of ubiquitous axiomatic method because its main objects (meaningful names and prehistories of ASMs devoted to select them) are inherently infinite and cannot be described taking traditional (Hilbert's Program) finite standpoint.

The duality of complete BSDT PL names, $c_{xi}x_j^{(i)}$, presented simultaneously as the name's meaningless random numerical identifier, $x_j^{(i)}$, and the name's meaningful context, c_{xi}, is rather similar to the duality introduced by Frege [Frege, 1892] to distinct the sense from the meaning of a word/sentence of a natural language. A proper name 'has as its meaning a definite object' while the name's sense 'serves to illuminate only a single aspect of the thing meant' [Frege, 1892]. The BSDT PL's name meaing, similar to Frege's, is a real-world thing given to an animal through its respective psychological state (Sect. 3), an analogue of Frege's notion of the 'idea' [Frege, 1892]. Thus, BSDT PL name meaning is actually a real-brain *physical* implementation of respective ASM hierarchy/ neural subspace representing a real-world thing. This inference almost completely coincides with the 'direct reference' view popular in philosophy – 'A name means an object. The object is its meaning' [Wittgenstein, 1922; 3.203]. The name's explicit meaning, $M_{\text{expl}}(x_j^{(i)})$, is its complete *symbolic* description, $c_{xi}x_j^{(i)}$, though this description is of course not the same as its *physical* implementation – particular real-brain neural subspace or the name's implicit meaning, $M_{\text{impl}}(x_j^{(i)})$ ([Gopych, 2009b], i.e. the BSDT PL reconciles two distinct roles of a name and the term ‘definition’ – to refer to anything nameable and to designate its description). *Context principle* – ‘never to ask for the meaning of a word in isolation, but only in the context of a proposition’ [Frege, 1884] – is also completely consistent with the BSDT PL. (Note, Frege’s German original *Bedeutung* [Frege, 1892] is translated into English as reference, meaning, denotation, signification, indication, designatum, nominatum, etc. Moreover, Frege himself used “the term ‘sense’ in two senses” – as a description of the name’s meaning and as ‘the way its reference is determined’. ‘Usually Fregean sense is now interpreted as the meaning’ [Kripke, 1990; p. 59, footnote 22]. Since meanings of BSDT PL names are indeed used in most general sense, we prefer the term ‘meaning’.)

On the other hand, the duality of BSDT PL names radically differs from Fregean or neo-Fregean duality. The infinity of meaningful BSDT PL names, $c_{xi}x_j^{(i)}$, and our infinity hypothesis are the reasons. Taken separatelly, BSDT PL names, $x_j^{(i)}$, are completely meaningless and have neither the ‘sense’ nor the ‘meaning’. They are the simplest conceivable numerical identifiers, $G^x_{ij} = x_j^{(i)}$ (Sect. 2), providing Gödel numbering of all the possible BSDT PL meaningful names/sentences/expressions, $c_{xi}x_j^{(i)} \in S_{cx0}$. BSDT PL Gödel numbers, G^x_{ij}, are written in binary string notations and represent the ordinals counting in a fixed but arbitrary chosen order appropriate real-world things whose properties are given to animals as *axiomatic* truths. Inherent randomness and uncomputability of BSDT PL names/Gödel numbers admit them to be interpreted as *ij*th fractions of Chaitin’s Ω, $x_j^{(i)} = G^x_{ij} = \Omega^x_{ij}$ (Sect. 3). Among infinite number of BSDT PL string names, $x_j^{(i)}$, because the set of them is complete (includes all possible variants) there are always the ones that in a system of notations code finite-in-length axioms, inference rules, and theorems of any axiomatic calculus. At the same time, we cannot guarantee that particular calculus’ (e.g. Whighthead and Russell’s [Russell, 1903]) axioms, inference rules and theorems, though infinite in number, exhaust the BSDT PL names. Indeed, according to Gödel’s incomplerteness theorem, that is not the case. Moreover, any attempt to syntactically attach to a meaningless string a meaning additional to its inherent one of being a number leads to contradictions, as in the case of famous liar (or Berry’s, cf. [Boolos, 1989]) paradox. Since BSDT PL meaningful names are always true, for them there is *no* liar paradox, *no* related contradictions, and *no* incompleteness in the sense of Gödel. Instead, the problem arises of vague relations between meanings of names of different levels (Sect. 3 and footnote 2). The root of this problem is in colored nonlocality of higher-level names, $u_s^{(r)}$, and our fundamental inability to strictly bound the meanings ($c_{ur}u_s^{(r)}$ and $c_{xi}x_j^{(i)}$, $c_{ur} = c_{xi}$) of names/Gödel numbers ($G^u_{rs} = u_s^{(r)}$ and $G^x_{ij} = x_j^{(i)}$) having different meaning complexities, $I(c_{ur}u_s^{(r)}) \neq I(c_{xi}x_j^{(i)})$, and related to different ultimate classes, namely $c_{ur}u_s^{(r)} \in S_{cu0}$, $c_{xi}x_j^{(i)} \in S_{cx0}$ assuming $c_{ur} = c_{xi}$ (Sects. 3, 4).

BSDT PL notion of meaning complexity (Sect. 5) embraces the notions of information/entropy [Shannon, 1948]) and Kolmogorov [Li, 1997] or algorithmic [Chaitin, 1998] complexity. Meaning complexity integrates the descriptions of ensemble properties and individual properties of things and provide a possibility of their quantitative comparing. Given the c_{xi}, since $x_j^{(i)} = G^x_{ij} = \Omega^x_{ij}$, the mentioned complexities for BSDT PL names, $x_j^{(i)}$, respective Gödel numbers, G^x_{ij}, and respective halting probabilities, Ω^x_{ij}, coincide with each other. Gell-Mann and Lloyd [Gell-Mann, 1996] combined in a finite manner Kolmogorov information and Shannon information/entropy to introduce an *effective complexity* of an ensemble in a string form – that is a loose counterpart to BSDT PL context complexity – and combined effective complexity with Shannon information/entropy to obtain total information over an ensemble – that is a loose counterpart to BSDT PL meaning complexity. For BSDT PL meaning complexity, it is its infiniteness that is given context its decisive distinction.

The BSDT PL convention on truth (Sect. 6) essentially differs from Tarski’s *convention T* [Tarski, 1935]. Tarski’s definition is *syntactical* and holds for a given axiomatically defined pair object-language/metalanguage only, whereas BSDT PL definition is *semantical* and uses the reality for checking the truths. Current truth-values of BSDT PL names are *unique* and *conclusive*, any hierarchy of them is neither possible nor requiered, in contrast to Tarski’s syntactical approach implying that for any metalanguage its meta-metalanguage can in turn be conceived and so up. For this reason, for each ‘higher-level’ pair metalanguage/meta-metalanguage its higher-level truth (the truth of sentences of respective higher-level metalanguage) could in general be defined. Tarski’s truths are *relative*, BSDT PL truths are *absolute* though sometimes ambiguous. An ambiguity arises for meanings (truths) of names of different levels – it is caused by the difference in their meaning complexities or colored nonlocalities of higher-level/fringe names. For names of a given level, their truths are always unambiguous and defined in the same way, as in Sect. 6. Name hierarchies (ontologies) and ambiguities between meanings (truths) of names of different levels are implemented (in the brain) by means of BSDT neural subspaces/ASM hierarchies for signal processing, memory, decision-making and consciousness [Gopych, 2008b, 2009b].

9. Conclusion

Instead of explicit (Fregean) use of the calculus of propositions, the BSDT PL employs the calculus of finite-in-length strings/vectors perfectly tuned to each other by their common infinite initial parts (contexts). Since strings/ vectors/names participated in BSDT PL inference rules (BSDT ASMs, Sect. 7) are finite, calculations on them can given the context be performed either exactly or, given any accuracy, approximately, e.g. [Gopych, 2006, 2008b]. In that sense BSDT PL predictions are strict and definite. On the other hand, since BSDT PL names/sentences are always to be attached to their infinite contexts, context's accuracy becomes crutial for the understanding of respective computations. For this reason, BSDT PL predictions are as accurate and definite as accurate and definite are infinite contexts supplied (estimated) by methods beyond the BSDT PL.

The BSDT PL above introduced is completely consistent with contemporary science and provides predictions (Sect. 3) testable in the experiment. It explains basic/involuntary behaviors of animals of simplest sociality (Sect. 6) and, consequently, gives the rules (though they are fundamentally incomplete) for designing their *approximate* copies, as close to their originals as possible. Practical semantic computations and designing the languages with capacities approaching natural languages are among other perspectives of BSDT PL possible applications.

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