# Human and Machine Understanding Of Natural Language Character Strings

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### Abstract

There is a great deal of variability in the way in which different language users understand a given natural language (NL) character string. This variability probably arises because of some combination of differences in language users' perceptions of its context-of-use (pragmatics), identity and mode of organization of its meaning bearing parts (syntax), and in the meanings assigned to those parts (semantics). This paper proposes a formalization of the syntax and semantics of NL character strings within a logical framework which is sufficiently flexible to represent the full breadth of possible ways of understanding NL character strings as influenced by different contexts-of use, beyond what can be represented in currently used predicate-logic-based frameworks. While the question of how language users understand NL character strings is ultimately a question in the psychology of language, it appears to us that, for the purposes of AGI, that question needs to be addressed within a logical framework which explicitly identifies the syntactic and semantic components that comprise that understanding, and which account – in formal terms – for differences in that understanding. Such a logical framework would provide a formal basis not only on which to address further psychological issues regarding human language understanding, but also for coherently imparting such understanding to machines.

## Purpose

In this paper, I attempt to formalize the notion of what it means to understand NL character string as a sentence, and to describe a mechanism whereby particular sentential readings of given character strings induce particular patterns of deductive connections among them [1]. Allowing that great variability appears to exist among language users regarding the patterns of deductive connections which they perceive to hold among given NL character strings and to include non-normal, i.e., atypical, patterns as well as normal ones, the question arises regarding how to formalize sentential readings of character strings broadly enough to induce such a range of perceived patterns. Predicate logic and its variants such as resolution logic [2], [3], and its extensions such as Montague logic [4], do not appear sufficiently flexible for formalizing sentential readings broadly enough. In particular, while their respective mechanisms for inducing patterns of deductive connections are both explicit and precise, as well as applicable to a wide range of NL character strings, the restrictions they impose on sentential readings are such as to be capable of inducing only a small range of normal patterns of deductive connections. Moreover their mechanisms are typically sequential rather than parallel, hence too slow in machine applications to meet envisioned AGI capabilities. Connectionist formalizations such as [5] appear even more restrictive in the kinds of deductive patterns which they induce and, while designed to use massively parallel mechanisms for inducing deductive patterns on NL character strings, their formalizations and proposed mechanisms have thus far been illustrated for a limited number of cases of the simplest types. In this paper we outline an alternative logic which appears minimally restrictive in the range of sentential readings it can represent and yet capable of supporting a massively parallel mechanism for inducing non-normal as well as normal patterns of deductive connections among them. There is not space to describe this mechanism in this paper, but it is described to some extent in [6].

## Key Notions

**Natural Language (NL) Character Strings.** By a *natural language (NL) character string* I mean an expression of natural language stripped of any structure beyond the ordering and spacing of its characters.

**Readings of NL Character Strings** [1]. By a *reading of an NL character string* I mean a language user's way of understanding it which includes an intuitive conceptualization of its meaning bearing parts[1] (syntax), and intuitive conceptualization of the meanings that the language user associates with those meaning bearing parts (semantics, where both conceptualizations are conditioned by a perceived context-of-use (pragmatics).

**Sentential Readings of NL Character Strings.** By a *sentential reading of an NL character string* I mean a reading of that character string as an assertion which can be judged as true or false. Sentential readings of a given NL character string can vary markedly among language users according to the way that they conceptualize its syntax and semantics and perceive its context-of-use[2].

**Sentential Reading Assignments (SRAs) on Sets of Character Strings.** By a *sentential reading assignment*

*(SRA)* on a set of NL character strings I mean an assignment of sentential readings to each character string in the set which *induces a pattern of deductive connections* among them.

**Normal and Non-Normal SRAs on Sets of Character Strings.** An SRA on a set of character strings is said to be *normal (non-normal)* to the degree that the patterns of deductive connections which it induces on the set is consistent (inconsistent) with language users' deductive intuitions relative to typical contexts-of-use.

## Readings: Formally Considered

**Formalizing Readings.** A reading of an NL character string c is formalized as a pair <Syn(c), Sem(c)> consisting of a *syntactic representation* Syn(c) of c, and a *semantic representation* Sem(c) of c. We assume a syntactic representation language L and a universe of discourse. Due to space limitations we summarize the internal structures of Syn(c) and Sem(c), as indicated below. (A fuller account can be found in [6].)

**Syntactic Representation Syn(c) of a Sentential Reading of Character String c.** There are three grammatical categories of expressions in the syntactic representation language L: *relation expressions, thing expressions,* and *modifier expressions.* In order to accommodate the differences which appear to exist in ways that different language users could understand given natural language word strings, we allow a very permissive grammar for L, called an "open grammar," which is one in which the syntactic representation component Syn(c) of a given (not necessarily sentential) reading of an NL character string c can be a relation expression, a thing expression, or a modifier expression[3]. For example, the syntactic representation component of the character string "love" could be a relation expression in one occurrence, a thing-expression in another occurrence, and a modifier-expression in a third. The syntactic representation component Syn(c) of a sentential reading of a character string c is composed of an n-place relation expression $r^n$ together with n thing expressions $a_1 ,\ldots, a_n$ which it relates, and together with three ordering functions p, q, t, on those n thing expressions (illustrated below). We schematically express Syn(c) as $r^n\ (a_1,\ldots,\ a_n)_{p,q,t}$, with the ordering functions as indicated. The relation expression $r^n$ is, in turn, composed of a sequence of modifier expressions applied to a base (i.e., modifier-less) relation expression (e.g., "give") together with m case expressions $b_1, \ldots, b_m$ (e.g., variously representing "agent", "patient", "recipient", and so on), each of which identifies the semantic role of one (or more) of the n thing expressions $a_1,\ldots,a_n$. Each $a_i$ is, turn, composed of a sequence of modifier expressions applied to a base (i.e., modifier-less) thing expression.

**Interpretations.** The description of Sem(c) makes essential reference to the notion of an *interpretation*, defined as follows: An *interpretation f on Syn(c)* is a function which assigns denotations to expressions in Syn(c) as follows: (i) f assigns to every n-place relation expression $r^n$ in Syn(c) a set $f[r^n\ ]$ of n-tuples of elements of the universe of discourse; (ii) f assigns to every thing expression $a_1$ in Syn(c) a set $f[a_1]$ of subsets of the universe of discourse; and assigns to every modifier expression m in Syn(c) a function f[m] which assigns tuples and sets of subsets of elements of the universe of discourse to tuples and sets of subsets of the universe of discourse. By virtue of what the interpretation f assigns to the relation expressions, thing expressions, and modifier expressions in Syn(c), f recursively assigns to Syn(c) a set f[Syn(c)] whose defining condition (called *the truth condition of Syn(c) under f*) is a statement in the set theoretic meta-language of L which expresses in set theoretic terms the content of Syn(c) relative to f. If this defining condition is a true statement of set theory, we say Syn(c) is *true* under the interpretation f, and otherwise that Syn(c) is *false* under the interpretation f. We restrict interpretations to *permissible* ones that render truth conditions comparable and computationally tractable. Roughly, the only way two permissible interpretations could differ would be in the denotations they assign to base relation expressions.

**Denotation of the Syntactic Representation Component Syn(c) of a Sentential Reading of c.** The truth condition of the denotation of the syntactic representation component Syn(c) under which Syn(c) is true is regarded as describing an "event" or "state of affairs" to the effect that the denotations of the n thing expressions $a_1, \ldots, a_n$ stand in the relation denoted by $r^n$ relative to three orderings p, q, and t on those thing expressions. The ordering p is called the *relative scope ordering* of $a_1, \ldots, a_n$ in Syn(c), the ordering q is called the *relative place ordering* of $a_1,\ldots, a_n$ in Syn(c), and the ordering t is called *the relative case ordering* of $a_1, \ldots, a_n$ in Syn(c). The *relative scope ordering p* determines the scopes of the governing modifiers on each $a_1, \ldots, a_n$. The *relative place ordering q* determines the order in which $a_1, \ldots, a_n$ are to be taken relative to the n-place relation denoted by $r^n$, in the sense that the thing expression $a_1$ is to occupy the p(i)th argument place of that relation. Finally, the *relative case ordering t* determines which of the cases $b_1, \ldots, b_m$ is associated with each of the thing expressions $a_1, \ldots, a_n$., in the sense that, for each i, $1 \leq i \leq n$, $t(a_i)$ is that case among $b_1, \ldots, b_m$ which applies to the thing expression $a_i$. For most sentences of English, case expression are usually placed adjacent to the thing expression they govern, and both relative scope and relative place orderings are usually the "identity orderings", that is, they coincide with the order of occurrence of the thing expressions they govern. But this is not the situation for all sentences of English, nor for sentences of many other languages. The syntactic structure of sentences must take into account each of these special orderings. For example, different *relative scope orderings p* correspond to the difference between "Every man loves some woman" and "Some woman is such that every man loves her", different *relative place orderings q* correspond to the difference between "Every man loves some woman" and "Some woman loves every man," and different *relative* *case orderings t* correspond to the difference between "Every man loves some woman" and "Every man is loved by some woman". We thus schematically express the syntactic representation component Syn(c) of a sentential reading of a character string c as $r^n(a_1, \ldots, a_n)_{p,q,t}$ where p is the relative scope ordering of c, q is the relative place ordering of c, and t is the relative case ordering of c. We refer to the elements of $U(f[a_i])$ for $1 \leq i \leq n$, as belonging to the ith domain of $f(r^n)$.

**Semantic Representation Sem(c) of a Sentential Reading of Character String c.** The semantic representation component Sem(c) of a sentential reading of c is the set of all denotations f[Syn(c)], as f ranges over all permissible interpretations of Syn(c) under which Syn(c) is true. Thus the semantic representation Sem(c) of a sentential reading of character string c expresses all states of affairs relative to permissible interpretations under which its syntactic representation Syn(c) is true.

## Sentential Reading Assignments (SRAs)

**Sentential Reading Assignments.** A *Sentential reading assignment (SRA) on a set of C of NL character strings relative to a set C^ of auxiliary NL character strings is an assignment of a sentential reading* <Syn(c), Sem(c)> to every character string c in C U C^. An SRA *induces a pattern of deductive connections on* C as a relation R between subsets C' of C and elements c of C *which holds just in case syn(c) is true under every permissible interpretation f under which, for every c' in C' U C^, Syn(c) is true under f.* The set C^ of auxiliary character strings can be regarded as a set of *assumptions* under the readings assigned to them, and which the language user perceives to be related to the readings assigned to the character strings in C, and which the language user regards as true. We will refer to C^ as an *assumptive set for C.*

**Normality of Patterns of Deductive Connections.** Normality of patterns of deductive connections is always relative to a context-of-use, which may be a typical one or an atypical one. When no reference is made to a context-of-use we regard the unreferenced context-of-use as being a *typical* one. A given pattern of deductive connections among given sentential readings of given character strings has a greater degree of normality than another pattern of deductive connections among sentential readings of those character strings *relative to a given context-of-use* if most language users would tend to regard the former pattern as more consistent with their deductive intuitions than the latter pattern relative to that particular context-of-use. A *normal pattern* of deductive connections among given character strings would be one which had a relatively high degree of normality relative to typical contexts-of-use and a *non-normal pattern* of deductive connections would be one which had a relatively low degree of normality relative to typical context-of-use.

**Normality of SRAs.** An SRA on C U C^ is regarded as *normal or non-normal, and as normal or non-normal to a given degree, relative to a given context-of-use-according as* the pattern of deductive connections which that SRA induces is normal, non-normal, normal to that degree, or non-normal to that degree relative to that context-of-use, that is, according as the pattern of deductive connections which that SRA induces is consistent, inconsistent, consistent to that degree, or inconsistent to that degree with the deductive intuitions of language users relative to that context-of-use.

**Normality of Readings.** A reading <Syn(c), Sem(c)> of an NL character string c is normal relative to a given context-of-use, and is normal (i.e., without reference to a context-of-use) if it is normal relative to typical contexts-of-use.

**Variability in SRAs among Language Users.** Variability in SRAs on a set C of character strings relative to the assumptive set C^ and relative to a context-of-use can derive from various sources: Variability in the character strings in C^ among language users, variability in the syntactic representations Syn(c) of the character strings in C U C^ assigned them, variability in the semantic representations of these character strings assigned them, and variability in the context-of-use relative to which the readings of character strings in CUC^ are made. Each of these three sources also allows for a large measure of possible variation in the normality of SRAs among language users.

## Examples

**Let C consist of the following character strings [4]:**

(1) John loves Mary.
(2) Mary is a person.
(3) John loves a person
(4) John does not love Mary.
(5) Something loves Mary.
(6) Mary is loved.
(7) Johns knows Mary.
(8) Mary is loved by John.
(9) Love loves love.
(10) Something loves love.

**Some Normal Patterns of Deductive Connections among Character Strings (1) – (10).** There are various possible patterns of deductive connections among sentential readings of (1) – (10) induced by SRAs which could reasonably be considered "normal" relative to some typical context-of-use. Some examples are given in Patterns (A), (B), and (C), below:

**Pattern (A):** This would be a pattern of deductive connections among (1) – (10) which included the following: (1) and (2) together deductively imply (3), but (1) alone does not; (1) deductively implies each of (5) and (6); (1) also deductively implies (7) if C^ includes a character string which expresses, "Whoever loves Mary knows her" under a suitable sentential reading; (1) and (8) deductively imply each other, hence (8) deductively implies each of (5) and (6) and, if C^ includes a suitable sentential reading of character string "Whoever loves Mary knows her" then (8) deductively implies (7) as well; (1) does not deductively imply (4), nor does (4) deductively imply (1); and neither (9) nor (10) deductively imply or are implied by any subset of (1) – (7). This (partial) pattern of deductive connections would be induced by an SRA in which "John", "Mary", and "love" were assigned the same denotation in each of their occurrences in (1) – (10), and in which C^ did *not* include a character string which expressed something like, "Mary is a person." (Mary may have been a cat or some other non-person).[4] The failure of (9) to imply (10) is due to the circumstance that we are considering normality relative to a *typical* context-of-use, and it is unlikely that there could be a typical context-of-use relative to which any sentential reading of (9) or (10) could be considered normal, that is, could enter into implications which were consistent with language users' deductive intuitions. On the other hand, one can imagine certain atypical contexts-of-use relative to which (9) and (10) could be considered normal. See Pattern (E) below.

**Pattern (B):** Another normal pattern of deductive connections among sentential readings of the character strings (1) – (10) would be induced by the same SRA as induced Pattern (A) with the exception that (1) no longer deductively implies (7) inasmuch as C^ no longer includes a sentential reading of "Whoever loves Mary knows her." Pattern (B) here is a diminution of Pattern (A).

**Pattern (C):** A third normal pattern of deductive connections among sentential readings of these character strings would be that induced by the same SRA as induced Pattern (A) with the exception that (2) is not now in C but is in C^, so that this Pattern (C) now includes the additional implication that (1) alone implies (3). Pattern (C) is an augmentation of Pattern (A).

**Some Normal and Non-normal Readings of Character String (1):** There is not sufficient space in this short paper to give a detailed indication of the structure of normal readings of character strings (1) - (10) for an SRA that would induce the above indicated pattern of deductive connections among them. However, we can indicate the structure of one reading N1 of (1) that could be assigned to (1) as part of a normal SRA on (1) – (10) that would induce the above Pattern (A). We later indicate the structure of two *non-normal* readings, namely readings NN2 and NN3, which would also induce Pattern (A).

**Normal Reading N1 <$Syn_1$(1), $Sem_1$(1)> of Character String (1):** In $Syn_1$(1), "loves" is syntactically marked as a two term relation whose first term is syntactically marked as an agent position and whose second term is syntactically marked as a recipient position, and "John" and "Mary" are syntactically marked as individual entities which occupy the agent and recipient positions, respectively. In $Sem_1$(1), we have an interpretation f1 of (1) relative to the syntactic component $Syn_1$(1) of (1) which is a function which assigns, as denotation of "loves" a set of pairs of entities of the domain of discourse, and which assigns, as denotations of "John" and "Mary" individual entities of the domain of discourse (as opposed to, say, classes or relations), and which is such that (1) is true under that interpretation f1 if and only if the pair which has the denotation of "John" as its first element and the denotation of "Mary" as its second element belongs to the denotation of "loves" that is, is one of the pairs in that denotation. Reading (1) of (1) would be a normal reading of the character string (1).

**Non-Normal Reading NN2 <$Syn_2$(1), $Sem_2$(1)> of Character String (1):** In $Syn_2$(1), "loves" is syntactically marked as a two term relation whose first term is syntactically marked as a recipient position and whose second term is syntactically marked as an agent position, i.e., the converse of the way "loves" is syntactically marked in $Syn_1$(1). In $Sem_2$(1) we have an interpretation f2 which is a function which assigns, as denotation of "loves" a set of pairs of entities of the domain of discourse, and which assigns, as denotations of "John" and "Mary" individual entities of the domain of discourse, and which is such that (1) is true under the interpretation f2 if and only if the pair which has the denotation of "John" as its first element and the denotation of "Mary as its second element belongs to the denotation of "loves" that is, is one of the pairs in that denotation. Reading NN2 is not a normal reading of character string "Johns loves Mary" but would be a normal reading of the character string "Mary is loved by John."

**Non-Normal Reading NN3 <$Syn_3$(1), $Sem_3$(1)> of Character String (1):** In $Syn_3$(1), "loves" is syntactically marked as a two term relation whose first term is syntactically marked as an agent position and whose second term is syntactically marked as recipient position, and "John" and "Mary" are syntactically marked as individual entities which respectively occupy the recipient and agent positions. In $Sem_3$(1), we have an interpretation f3 of (1) relative to the syntactic component $Syn_2$(1) of (1) which is a function which assigns, as denotation of "loves" a set of pairs of entities of the domain of discourse, and which assigns, as denotations of "John" and "Mary" individual entities of the domain discourse, and which is such that (1) is true under that interpretation f3 if and only if the pair which has the denotation of "Mary" as its first element and the denotation of "John" as its second element belongs to the denotation of "loves" assigned by f3. Reading NN3 of (1) is not a normal reading of the character string "John loves Mary" but would be a normal reading of the character string "Mary loves John."

**Some Non-Normal Patterns of Deductive Connections Among Character Strings (1) – (10):** There are also various patterns of deductive connections among sentential readings of (1) – (10) induced by SRAs which could *not* reasonably be considered "normal" relative to some typical context-of-use. Some examples are given Patterns (D), (E), and (F) below.

**Pattern (D):** A fourth pattern of deductive connections among the character strings (1) – (10) is a non-normal one which would be induced by an SRA which assigned readings to (1) and (3) in which the character string "John" in (1) received a different denotation than the denotation it received in (3) (which could occur in a context-of-use where there were two individuals, say, one an individual named "John" who loved "Mary", and another named "John" who loved no one). This non-normal way of understanding (1) – (10) induces a pattern of deductive connections which is very different from any of the three earlier indicated patterns; in particular, (1) and (2) together no longer deductively imply (3).

**Pattern (E):** A fifth pattern of deductive connections among the character strings (1) – (10) is another non-normal one induced by an SRA such that: (i) the second occurrence of "love" in (9) and the second occurrence of "love" in (10) are each syntactically represented as a 2-place relation expression whose first term is syntactically marked as an agent position and whose second term is syntactically marked as a recipient position. The first and third occurrences of "love" in (9) are each syntactically marked as individual entities and respectively occupy the agent and recipient positions of the syntactic representation of the second occurrence of "loves" in (9). Similarly, the occurrence of "Something" in (10) and the second occurrence of "love" in (10) are each syntactically marked as individual entities, and respectively occupy the agent and recipient positions of the syntactic representation of the second occurrence of "loves" in (10). This non-normal reading of (9) and (10) induces a pattern of deductive connections among (1) – (10) which, unlike the case with Patterns (A) – (D) above, now includes the implication of (10) from (9).

**Pattern (F):** A sixth pattern of deductive connections among these character strings is another non-normal one induced by an SRA which assigns "love" a denotation in (8) which is opposite that assigned to "love" in (1) and (6), such as, for example, that its meaning in (1) and (6) is its usual meaning, while its meaning in (8) is an ironic one, i.e., to mean "hate". This is non-normal way of understanding (1) – (10) induces a pattern of deductive connections which is very different from any of the four earlier indicated patters; in particular, (1) and (8) no longer deductively imply each other, and (8) no longer deductively implies (6). Indeed, we now have the bizarre implication of (1) from (4) and (4) from (1).

**Relative Degree of Normality of Above Sample Patterns of Deductive Readings.** Recalling that the degree of normality of a given pattern of deductive connections is the degree to which language users would tend to regard the pattern of deductive consequences as consistent with their deductive intuitions relative to a typical context-of-use, we would order the above six patterns (A) - (F) as being in decreasing order of normality.

## Internal Structure of Sentential Readings

**Internal Structure of the Syntactic Component of a Reading.** The syntactic component Syn(c) of a reading of a character string c describes the underlying syntactic structure of c as a pattern of interconnections of its meaning-bearing parts. The minimal meaning-bearing parts of a syntactic representation of a character string are called *representational morphemes.* The syntactic representation of that character string is recursively built out of representational morphemes into a syntactic representation Syn(c) of the entire character string.

**Internal Structure of the Semantic Component of a Reading.** The semantic component Sem(c) of a reading of a character string c assigns a set-theoretical meaning to every meaning-bearing part identifies in the syntactic representation component of that reading, and thereby interprets that syntactic representation, proceeding from its (syntactically) smaller meaning-bearing parts and, by a recursive process, ultimately to the full pattern of interconnections of those meaning-bearing parts. The semantic component is specified in *semantic axioms,* which state the set theoretical meanings to be assigned to meaning-bearing parts.

**Parts: Of Character Strings and of Syntactic Representations.** Parts of character strings will be distinguished from parts of syntactic representations of character strings. The notion of "part" as it applies to character strings is to be understood in the sense that the sequence of letter and blanks comprising the part in question is a subsequence of the sequence of letters and blanks comprising the containing character string, and is not intended to be semantically interpretable. On the other hand, the notion of "part" as it applies to syntactic representations of character strings, is intended to be semantically interpretable; that is, "part" in this latter sense means "interpretable part", whereas, in the case of character strings, it does not.

**Implicitly and Explicitly Realized NL Morphemes.** As remarked earlier, a deductive reading of a character string specifies a system of syntactically and semantically inter-related representational morphemes. Consistent with standard linguistic usage, I regard the notion of a natural language morpheme as a theoretical construct, i.e., as an abstract entity that is "realized" in a given character string in one of two ways: (a) explicitly, indicated in part by and corresponding to a specific part of that character string called a "morph"; (b) implicitly, indicated solely by global relations among the parts of that character string, involving factors such as order of occurrence, juxtaposition, intonation patterns (if oral), perceived grammatical and semantic relationships among character string parts, etc. A natural language morpheme that is explicitly realized in a part of (i.e.: as a morph occurring in) a given character string is also said to be explicitly marked in that character string by that part (i.e., by that morph). A natural language morpheme that is implicitly realized in a given character string by certain global relations among its parts is said to be implicitly marked in that character string by those relations.

**Logical and Lexical NL Morphemes.** The intended distinction between logical and lexical natural language morphemes is an intuitive semantic one: roughly, a lexical natural language morpheme is one which intuitively denotes some entity, relation, or characteristic of an entity or relation, such as "boy", "walks", "hits", "tall", "slowly", etc; whereas a logical natural language morpheme is one that intuitively denotes some way of operating on what lexical natural language morphemes denote, and expressed by character strings such as "all", "and", "not", "many", "after", etc. We distinguish the notion of an NL morpheme from that of a representational morpheme, which is an actual expression of a syntactic representation of a character string which occurs as an explicit part of that syntactic representation.

**Morphemic Base Assumption.** We assume that a language user's intuitive judgments regarding the degree of normality of a given pattern of deductive connections among the character strings in a given set C of character strings derive from this or her intuitive judgments regarding semantic interconnections among the logical natural language morphemes realized in the character strings of C U C^, and regarding semantic interconnections among the lexical natural language morphemes realized in the character strings of C U C^.

**Semantic Interconnections among Logical Natural Language Morphemes Realized in (1) – (10).** Applying the Morphemic Base Assumption to the pattern (A) of deductive connections, we would conclude that the particular deductive connections of (A) derived ultimately from intuitive judgments regarding semantic interconnections among the logical natural language morphemes realized in the character strings (1) – (10), which included in part, the explicit logical natural language morphemes "not" and "is", as well as, various implicit logical natural language morphemes. We are suggesting, then, that the typical English speaker who understood the meanings of these logical natural language morphemes would assent to the above pattern of deductive connections even if he did not understand the meanings of the lexical natural language morphemes "John", "Mary", "love", and "person" occurring there.

**Semantic Interconnections Among Lexical Natural Language Morphemes Realized in (1) – (10).** On the other hand, an English speaker's intuitive judgment that (1) deductively implied (7) would derive *both* from his intuitive judgments regarding semantic interconnections among the logical natural language morphemes occurring in character strings (1) and (7), *and* from his intuitive judgments regarding the semantic interconnections between the lexical natural language morphemes "loves" and "knows" (such as, for example, that loving a person meant, in part, knowing that person).

## Endnotes

1. This is not to say that the language user is explicitly conscious of any of these components, or how they condition his or her understanding of given character strings, or of the patterns of deductive connections they induce among them. Rather, our analysis is forwarded as a "competence" model of their role in language users' understanding of those character strings and how that understanding induces perceived patterns of deductive connections among them.
2. The notion of context-of-use is treated in this paper as a primitive notion to mean something like *the real-world situation in which given character strings are produced.*
3. We refer to this type of grammar as an "open grammar" inasmuch as the grammatical category in which a given character string is syntactically represented is not fixed, but can vary from one occurrence to another.
4. For simplicity we express character strings in their ordinary appearance as sentences rather than as a concatenation of individual alphabetic symbols and spaces.

## References

[1] Tripodes, P.G., *A Theory of Readings.* Unpublished Manuscript.

[2] Wos, L., *Automated Reasoning: 33 Basic Research Problems,* Prentiss-Hall, Englewood Cliffs, New Jersey, 1988.

[3] Bachmair, L. & Ganzinger, H., "Resolution Theorem Proving," in A. Robinson & A. Voronkov, eds. *Handbook of Automated Reasoning. Vol I.* Elsevier Science, Amsterdam, chapter 1, pp 21-97. 2001.

[4] R. Montague, English as a Formal Language, in R. Thomason, ed., *Formal Philosophy. Selected Papers of Richard Montague,* Yale University Press, New Haven. Pp 188-221. 1974.

[5] Shastri, L., & Ajjanagadde, V., "From simple association to systematic reasoning: A connectionist representation of rules, variables and dynamic bindings using temporal synchrony," in *Behavioral and Brain Sciences,* 16, 417-494. 1993.

[6] Tripodes, P.G., "Real time machine deduction and AGI," in P. Wang, B. Goertzel, & S. Franklin, eds. *Artificial General Intelligence.* Amsterdam, IOS Press. 2008.