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# LOGICA TRIANGULI

LÓDZ, NANTES, SANTIAGO DE COMPOSTELA

2

1998

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Papers for publication within the area of interest of the journal are invited. They should be written in English and conform the conditions indicated on the third page of the cover and may be sent to any of the persons indicated above.

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## SEMI-SENTENCES, SEMI-STRINGS AND SEMI-GRAMMATICAL RULES IN PROLOG

Alejandro SOBRINO, José Angel OLIVAS, Santiago FERNÁNDEZ

### Abstract

The aim of this work is to analyse the concept of semi-sentence from a linguistic, formal and computational point of view. A semi-sentence can be characterised as a sentence which, from a grammatical perspective, is neither absolutely correct nor incorrect (in the sense that a speaker-listener of the language in which it is uttered understands it). This study focuses on:

- a characterisation of the semi-sentences in the setting of the grammar of a language. This study will help to analyse in depth the concept of grammaticality [3];
- the correlate of semi-sentences in formal languages, i.e., semi-strings, which arise from applying productions that deviate from that which is strictly permitted by the rules of grammar [6];
- a Prolog program for handling semi-grammaticality in a computational manner [2].

These aspects are dealt with in an introductory way, and the purpose of this paper is not to treat them generically, rather they are adapted to specific examples.

### 1. Linguistic vagueness and grammatical vagueness

The most common type of linguistic vagueness, and also the one that is most alluded to, is the referential one; that is, vagueness that arises by way of which a word signifies an object. This type of linguistic vagueness is referred to more specifically as semantic vagueness. From this point of view, it is said that a word is vague when it does not denote its referent in a precise and unmistakable manner; that is, when there are objects for which it is doubtful that they are significantly well represented by this word. When this word refers to collections or classes of objects, they give rise to a fuzzy set. Semantic vagueness has been treated in a formal way in the setting of fuzzy formal semantics [7].

There are other topics of linguistic vagueness which are less common than semantic vagueness, such as:

- phonological vagueness, present, for example, in the phonic recognition of dialectal usage of a language;
- morphologic vagueness, which accompanies the deficient characterisation of classes of words by virtue of their endings;
- syntactic vagueness, which refers, for example to the absence of regularities in the format of dative clauses, or;
- grammatical vagueness, present in grammatical classifications, in which the categories are grouped in a "squishy" manner [4] rather than a precise one, as will be seen subsequently.

This paper deals with topics that are related to grammatical vagueness; it will specifically deal with the study of semi-sentences, sentences which from a grammatical point of view are neither totally correct, nor incorrect; i.e., sentences which are more grammatical than ungrammatical. The study of semi-sentences is relevant:

- in the field of natural language, in order to analyse in depth the concept of an almost grammatically correct sentence, as well as the understanding that a speaker-listener of a language has of these sentences, in spite of their relative malformation. In this context the distinction between grammaticality and acceptability will be useful
- in the area of formal languages, in order to lay the foundations for the development of grammars which enable the generation of strings which deviate from that which the production rules strictly permit
- from a computational point of view, processing semi-sentences leads to natural language man-machine interfaces that are flexible, not rigid.

## 2. Notes for a semi-sentence theory

A study of grammatical vagueness is to a great extent an investigation into whether linguistic objects may be grouped into grammatical categories with crisp boundaries, or whether, on the contrary, there are objects which are susceptible to belonging to more than one category, or to being a member of one category more clearly than of another. If the latter holds, then one would have to accept the existence of grammatical categories with fuzzy boundaries, to which linguistic objects would belong to a certain degree.

English grammar has this peculiarity [4]. Written in Italics are some of the categories that are central to this grammar and in normal text the categories of transition between the central categories,

*Verb* > Present participle > Perfect participle > Passive participle > *Adjective* > Preposition (?) > "Adjectival noun" (e. g. fun, snap) > *Noun*

Ross verifies a gradation amongst these. In the prototypical categories, oppositions work in a binary manner; a linguistic fact either belongs or does not belong to the category being considered. In the transition categories, facts are evaluated according to their distance from the prototypical category. This is the case of the participle. If it is the present participle, it exceeds certain grammatical tests typical of verbs; but if it is the past participle, it shares more characteristics with the "adjective" category than the "verb" one.

These examples leads us to distinguish in grammatical classifications between:

- central elements, with genuine membership, and
- peripheral elements, with degré of membership to the category.

A grammatical model which enables this flexible, non rigid grouping of linguistic facts will take on notions such as unstable syntactic constructions, loosely fitting morphological units, semi-productive morphological schemes or semi-sentences. We will now go on to discuss some characteristics of semi-sentences.

The characterisation of the semi-sentence presupposes, with respect to grammaticality, an alternative to the dichotomic grammatical/non grammatical opposition. In this context, the internal or external character of negation enables a three-way distinction:

- grammatically correct sentences
- grammatically non correct sentences, and
- grammatically incorrect or ungrammatical sentences

The grammatically non correct sentences are referred to as semi-sentences (SemiS). An example of a SemiS is:

*An idea occurred me or A sandwich I ate.*

The lack of total grammaticality can be given by:

- a deficient syntactic organisation
- a insufficient semantic analysis

In the above examples it can be observed that the malformation is brought about by deficient syntactic organisation. But not all semi-sentences arise from syntactic problems. Irregularities in the semantic stratum explain, as can be seen below, the absence of complete grammaticality, such as in the sentence *The trial runs fast*.

A semi-sentence theory should explain how the knowledge that the speaker has of the language enables him to understand utterances which are neither totally grammatical, nor ungrammatical. If we consider the knowledge that a speaker has of his grammar and the capability to categorize every linguistic fact, a SemiS generates a double perplexity:

- if the SemiS is not generated, then the grammar is incomplete,
- if the SemiS is generated, the grammar fails.

This perplexity should be solved in a non dichotomic manner by a theory that deals with these linguistic entities.

One way of classifying sentences produced by semantic irregularities is to distinguish different levels of structural description of a sentence [3]. Let us call each one of these levels formatives [1]. Let us suppose then that we have  $m$  levels of formatives  $f^1, f^2, \dots, f^m$  each one with  $n$  index  $f^1_1, f^1_2, \dots, f^1_n$  in such a manner that the sub-index 1, 2, ...,  $n$  indicate a greater degree of specificity in the structural description. Let the sentence be the one already quoted:

*The trial runs fast* (S1)

This is a sentence that is syntactically well ordered, but about which it cannot be said that it is as grammatically correct as the sentence: *The athlete runs fast*. The anomaly is to be found in the semantic component.

Let us now go on to specify different levels of formatives with reference to the type of linguistic actions that they describe. Let us accept that, in level one 1,  $f^1_1$  represents words. In level 2,  $f^2_1$  represents nouns,  $f^2_2$  verbs,  $f^2_3$  adverbs and  $f^2_4$  articles. Lastly, in level 3 classes of formatives which are subclasses of those presented in 2 are represented:  $f^3_1$  represents the names of inanimate objects,  $f^3_2$  verbs of action  $f^3_3$ , adverbs of mode and  $f^3_4$  definite articles.

Thus (S1) has three possible levels of structural representation (according to the formatives distinguished):

- In level 1,  $f^1_1$ , repeated as many times as the number of words there are.
- In level 2,  $f^2_4 + f^2_1 + f^2_2 + f^2_3$ , which is the equivalent of Art + N + V + Adv.
- Lastly, in level 3,  $f^3_{4d} + f^3_{1i} + f^3_{2a} + f^3_{3mod}$ , where d, i, a and mod represent the sub-categorisations determinate, inanimate, ..., of the categories differentiated in level 2.

Given a grammar that has two descriptive levels, it is possible to say something about the grammaticality of (S1):

- In level 1, the description is very generic, and will give any series of words as being grammatical, including, for example, (S1).
- Levels 2 and 3 constitute successive refinements of 1. Level 2 reveals an initial structure of (S1): Art + N + V + Adv. As represents good syntactical ordering, according to English grammar it is possible to generate (S1).

In spite of sharing the structural description of (S1) with level 2, level 3 impedes the generation of this sentence. There is a structural rule of the constituents, which indicates that a verb of motion only accompanies nouns marked as "animate", as in the sentence "*the athlete runs fast*". Level 2 permits the generation of the semi-sentence (S1), as its level of grammatical analysis is not sufficiently fine. In level 2 (S1) does not contravene the rule that it transgresses in level 3.

In agreement with this form of grammatical description, it can be said that a semi-sentence is a sentence that is at the same time both grammatical (level 1 and 2) and non-grammatical (level 3).

Nevertheless, even within the same level of structural description, there are sentences that are not totally grammatical with respect to others which are so. These are deviations that are characterised in the syntactic stratum. Such is the case with *A sandwich I ate* (in comparison with the grammatical sentence *I ate a sandwich*).

A common way of explaining a SemiS from a syntactic point of view contemplates three forms of deviation from what can be considered as being prototypical sentences, obtained from standard syntactic derivations. The most simple types of variant are:

- inversion
- addition
- deletion

which can be summarised in the following typical format,

<u>Format</u>	<u>Name</u>
...AB... → ...BA...	Inversion
...AB... → ...A...	Deletion
...A... → ...BA...	Addition

*Examples* (in the same order):

I ate a sandwich → A sandwich I ate  
 I ate a sandwich → I ate sandwich  
 I ate a sandwich → I ate a sandwich big

Note that on the left side of the productions there is a totally grammatical sentence, whilst on the right there are semi-sentences.

In a paradigmatic way, the property known as deletion shows that, for a given class of words, no universal rule can be put forward as regards the possibility of (non) deletion in sentences without the grammaticality (vagueness) or meaning (ambiguity) of the sentence being altered [5]. The following examples show cases of grammatical ambiguity. (The symbol (\*) will be used for “can be deleted” and \*( ) for “cannot be deleted”.)

Following Ross [4], we show the deletion of three classes of words: prepositions, adjectives and nouns.

- Deletion of prepositions.
  - Your perfume surprised(\*to) me
  - It was surprising, your perfume \*(for) me.
- Deletion of adjectives
  - Sarah is like (\*to) a doll
  - Sarah is [near] \*(a) doll
- Deletion of nouns
  - I'm sorry (\*(about) the fact) that you didn't come yesterday
  - (The fact) remains that they accused you

The deletion property shows how some grammatical elements such as “to” and “the fact” can sometimes be suppressed (or not) in sentences without loss of grammaticality.

Up until now, some forms of classifying or generating semi-sentences have been shown. Nevertheless, a theory of semi-sentences should give a measurement of the degree of the good formation of a sentence, an evaluation of its degree of grammatical deviation. A plausible proposal should make it depend on the degree of addition/deletion and the degree of inversion of the element or elements that give rise to the grammatical deviation.

The degree of accessibility is the degree of mobility of the element or linguistic action inside the sentence (the element under consideration is written in italics).

- 1
  - i. It is possible that George will sign up for French *next year*.
  - ii. *Next year* it is possible that George will sign up for French.
  
- 2
  - i. The man with the moustache *whom I saw yesterday* is the cousin of the inspector.
  - ii. The man with the moustache is the cousin of the inspector *whom I saw yesterday*

In 1. the sentence has the maximum degree of accessibility for the expression "*next year*". Hence the sense and reference for the sentences (1.i) and (1.ii) do not change in spite of the fact that the ordering of the lexical elements being different. In 2, on the other hand, the degree of accessibility in the sentence of the relative clause "*whom I saw yesterday*" is minimum; by changing the position the sense of the sentence it changed, as is shown by a comparison of (2.i) and (2.ii).

The degree of addition is the degree of possibility of encrustation of an element in the sentence, for example,

Base sentence: It may rain.

- 3
  - (i). It may rain *tomorrow*.
  - (ii). *Tomorrow* it may rain.

Base sentence: I'm sorry that John is like that.

- 4
  - (i). I'm *always* sorry that John is like that.
  - (ii). I'm sorry that John is *always* like that.

In 4, the possibility that the sense of the phrase may change significantly by altering the position of the word in Italics is maximum,

which is not true of 3. Note how in these examples, the words in Italics do not give rise to cases of grammatical vagueness, but rather of grammatical ambiguity, which it possible to recognise immediately if a tree is drawn up for each of the sentences. They simply change the meaning of the sentences and not their grammaticality. If the encrustation and the mobility of an element do not give rise to an alteration in the meaning (in this case the sentence will still be in accordance with the grammatically established rules) but lead to the transgression of these rules, then we will have a case of grammatical vagueness. The smaller the degree of encrustation and mobility, the greater the transgression will be, so that a semi-sentence will be less grammatical the closer the product of these factors approaches zero.

Lastly, we deal with a methodological matter. It is interesting to analyse whether the comprehension of a semi-sentence can be explained as it entails a small deviation with respect to a grammatical regularity, or whether it is due to our cognitive ability. In other terms, if the semi-sentences are not grammatical, but are acceptable as sentences, as they enable communication with a good part of the speakers of a language, or if they allow communication, as they bear a resemblance to totally grammatical sentences. Whilst "grammaticality" is a term that belongs to the sphere of linguistics and refers to a normative conception, acceptability is a term that belongs to the sphere of sociolinguistics, and has to do with the description of language. Acceptability enables us to think about evaluating a sentence as a semi-sentence, and even a degree depending on the acceptability that the sentence has in the linguistic community. This evaluation would not be possible for a totally grammatical sentence, which in such a way is independent of its acceptation. This links up with an important theoretical matter, but one which will not be discussed in this work: whether grammar should be normative or, on the contrary, it should respond to linguistic actions just as they appear, and thus, to their deviations as well.

Up until now we have given no more than an outline of some elements for a semi-sentence theory. Due to the complexity of natural languages, the construction of this is beyond the scope of this work.

### 3. Semi-grammaticality and semi-strings

The objective of this section is to define cases of grammatical vagueness in the context of a language generated by a Chomsky's formal grammar.

Given a formal grammar,  $G = \langle \Sigma_T, \Sigma_{NT}, S, P \rangle$ , where

$\Sigma_{NT}$  is the non-terminal vocabulary

$\Sigma_T$  is the terminal vocabulary

$S$  is the initial symbol or axiom

$P$  is the set of production rules,

It is considered that imprecise strings (semi-strings) can be produced in the same manner as semi-sentences are formed; that is, by:

- Inversion. A string that is similar to a grammatical string is produced, the difference being that the elements are in a different order (if the elements are terminal or non-terminal will be indicated by the type of grammar that is being defined -context sensitive, context free, ..., etc.-)
- deletion. A string that is similar to a grammatical string is produced, except that it has less terminal symbols than the grammatical string with which it is compared.
- A string that is similar to a grammatical string is produced, except that it has more terminal symbols than the grammatical string with which it is compared.

*Example.*

Let  $G = \langle \{a, b, c\}, \{S, A\}, S, P \rangle$ ,

$P$ :

$S \rightarrow aSa \mid bB$

$B \rightarrow cB \mid c$

Some possible productions:

*Without deviation*

<u>Production Rules</u>	<u>Strings</u>
(the same)	-bc (1 <sub>2</sub> , 2 <sub>2</sub> ), where N <sub>n</sub> is rule N, alternativity n
	-abca (1 <sub>1</sub> , 1 <sub>2</sub> , 2 <sub>2</sub> )

*With deviation by*

*\*Inversion*

<u>Production Rules</u>	<u>Strings</u>
$S \rightarrow aSa Bb$	-cb (1 <sub>2</sub> , 2 <sub>2</sub> )
$B \rightarrow Bc c$	-acba (1 <sub>1</sub> , 1 <sub>2</sub> , 2 <sub>2</sub> )

*\*Deletion*

<u>Production Rules</u>	<u>Strings</u>
$S \rightarrow \_Sa aS\_ B\_$	$-\lambda$ (1 <sub>3</sub> , 2 <sub>2</sub> )
$B \rightarrow B\_ \lambda$	-a (1 <sub>1</sub> , 1 <sub>3</sub> , 2 <sub>2</sub> )

*\*Addition*

<u>Production Rules</u>	<u>Strings</u>
$S \rightarrow \{a,b,c\}aSa aSa\{a,b,c\} \{a,b,c\}bB bB\{a,b,c\}$	-abc (1 <sub>3</sub> , 2 <sub>3</sub> )
$B \rightarrow \{a,b,c\}cB cB\{a,b,c\} c$	-cbc (1 <sub>3</sub> , 2 <sub>3</sub> )

One question that arises is whether some type of quantification of the deviation of the string may be given and how. One possible (and partial) answer is to make it depend on some type of *ratio* between the number of symbols (NS) in the string and the anomalous symbols (AS), such as, for example:

$$\text{Degree of correctness of a string (DV)} = \\ = (|NS| - |AS| \div |NS|)_{\text{inversion}} \times (|NS| - |AS| \div |NS|)_{\text{deletion}} \times (|NS| - (|AS| \div |NS|)_{\text{addition}}),$$

*Example:*

If we take *bc* and *abca* as grammatical strings (generated with no deviation), the grammaticality calculus for the semi-strings generated from deviation by inversion (there are not addition and deletion) will be carried out in the following way:

$$\text{For } cb, DV = 2 - 2 \div 2 = 0$$

$$\text{For } acba, DV = 4 - 2 \div 4 = 0.5$$

This outline for a quantitative calculus of the string deviation is an initial approach, but a more developed study is beyond the scope of this work.

#### 4. Semi-sentences and Prolog

Semi-sentences can be analysed from a computational perspective as being generated by semi-grammatical rules in Prolog. Let be a simple grammar that generates grammatically correct sentences for a small fragment of English:

$$\begin{aligned} O &\rightarrow NP + V + NP \\ NP &\rightarrow Art + Noun \\ V &\rightarrow Verb \end{aligned}$$

where O, NP and V are non-terminals and Art, Noun and Verb are terminals.

This grammar could be written in Prolog thus:

```
sentence(List1, Rest):-
    np(List1, List2),
    verb(List2, List3),
    np(List3, Rest).

np(List1, Rest):-
    article(List1, List2),
    noun(List2, Rest).

article([article|Rest], Rest).

noun([noun|Rest], Rest).

verb([verb|Rest], Rest).
```

This grammar does not generate specific sentences, rather sentence structures of the type article-noun-verb-article-noun. An example of a sentence of this type is *The boy eats the sandwich*. We can modify its rules by the inversion, deletion and addition variants. The results will be grammatical, non-grammatical and semi-grammatical structures. These enable us to generate semi-sentences. This action can be implemented in the grammar by giving the value 1 to those rules that lead to grammatical sentences, 0 to those that lead to non-grammatical sentences, and 0.5 to those that lead to semi-sentences. As in order to generate an expression various rules are used, and these may have different values, the value of the resulting expression will be the minimum of the

value of all the rules used to generate it. In this way we will have the following variants in the sentence level:

*Without deviation*

```
sentence(List1, Rest, Deg_sent):-
    np(List1, List2, Deg_sub),
    verb(List2, List3, Deg_verb),
    np(List3, Rest, Deg_do),
    minimum([Deg_sub, Deg_verb, Deg_do, 1],
Deg_sent).
```

*With deviation by*

*\*Inversion*

```
sentence(List1, Rest, Deg_sent):-
    verb(List1, List2, Deg_verb),
    np(List2, List3, Deg_sub),
    np(List3, Rest, Deg_do),
    minimum([Deg_sub, Deg_verb, Deg_do, 0.5],
Deg_sent).
```

```
sentence(List1, Rest, Deg_sent):-
    np(List1, List2, Deg_do),
    np(List2, List3, Deg_sub),
    verb(List3, Rest, Deg_verb),
    minimum([Deg_sub, Deg_verb, Deg_do, 0.5],
Deg_sent).
```

*\*Deletion*

```
sentence(List1, Rest, Deg_sent):-
    np(List1, List2, Deg_sub),
    verb(List2, Rest, Deg_verb),
    minimum([Deg_sub, Deg_verb, 1], Deg_sent).
```

```
sentence(List1, Rest, Deg_sent):-
    verb(List1, List2, Deg_verb),
    np(List2, Rest, Deg_do),
    minimum([Deg_verb, Deg_do, 1], Deg_sent).
```

```
sentence(List1, Rest, Deg_sent):-
  np(List1, List2, Deg_sub),
  np(List2, Rest, Deg_do),
  minimum([Deg_sub, Deg_do, 0], Deg_sent).
```

```
sentence(List1, Rest, Deg_sent):-
  np(List1, Rest, Deg_sub),
  minimum([Deg_sub, 0], Deg_sent).
```

```
sentence(List1, Rest, Deg_sent):-
  verb(List1, Rest, Deg_verb),
  minimum([Deg_verb, 1], Deg_sent).
```

#### *\*Addition*

A complement may be included before or after any one of the components of the sentence, semi-sentences thus being obtained (i.e., rules with a value of 0.5) in all cases, except in the case in which the complement is in final position. In this case a grammatically correct sentence would be generated. This is supposing that the complement is grammatical and syntactically compatible with the sentence to which it is added. This occurs with *The boy eats the sandwich with gusto* and *The boy eats the sandwich from the plate*. In any other case, the result will be grammatically incorrect sentences.

At a syntagmatic level we could obtain the following variations:

#### *Without deviation:*

```
np(List1, Rest, Deg_np):-
  article(List1, List2, Deg_det),
  noun(List2, Rest, Deg_noun),
  minimum([Deg_det, Deg_noun, 1], Deg_np).
```

#### *With deviation by*

#### *\*Inversion*

```
np(List1, Rest, Deg_np):-
  noun(List1, List2, Deg_noun),
  article(List2, Rest, Deg_det),
  minimum([Deg_det, Deg_noun, 0], Deg_np).
```

*\*Deletion*

```
np(List1, Rest, Deg_np):-
    noun(List1, Rest, Deg_noun),
    minimum([Deg_noun, 0.5], Deg_np).
```

```
np(List1, Rest, Deg_np):-
    article(List1, Rest, Deg_det),
    minimum([Deg_det, 0], Deg_np).
```

*\*Addition*

An adjective may be included before the noun. We thus generate a syntactically correct noun phrase (value 1). If the adjective were to come after the noun, the rule would have a value of 0.5, and if it came before the article it would be ungrammatical. For example, a grammatically correct noun phrase would be *The blond boy*. One with a value of 0.5 would be *The boy blond*, and an ungrammatical one *Blond the boy*.

At word level (level 2), variations cannot be considered, although, as has previously been pointed out, a degree of classification of a word with respect to the category to which it belongs can be established. This option will not be considered in this paper, as the grammar does not generate specifically English sentences, rather it generates types of sentences. Thus, the rules for the word category would be:

```
article([article|Rest], Rest, 1).
```

```
noun([noun|Rest], Rest, 1).
```

```
verb([verb|Rest], Rest, 1).
```

The procedure calculating the minimum is as follows:

```
minimum([X], X).
minimum([A, B|C], X):-
    A =< B,
    minimum([A|C], X),
    !.
minimum([A, B|C], X):-
    A > B,
    minimum([B|C], X).
```

Given this code, the following goals may be put to the compiler:

- Grammatical sentences generated by the compiler.

In code:

```
sentence(Sentence, [], 1).
```

The compiler answers:

```
Sentence = [article,noun,verb,article,noun]
```

```
Sentence = [article,noun,verb]
```

```
Sentence = [verb,article,noun].
```

```
Sentence = [verb]
```

- Semi-grammatical sentences generated by the compiler.

```
sentence(Sentence, [], 0.5).
```

The compiler answers:

```
Sentence = [article,noun,verb,noun]
```

```
Sentence = [noun,verb,article,noun]
```

```
Sentence = [noun,verb,noun]
```

```
Sentence = [verb,article,noun,article,noun]
```

```
Sentence = [verb,article,noun,noun]
```

```
Sentence = [verb,noun,article,noun]
```

```
Sentence = [verb,noun,noun]
```

```
Sentence = [article,noun,article,noun,verb]
```

```
Sentence = [article,noun,noun,verb]
```

```
Sentence = [noun,article,noun,verb]
```

Sentence = [noun, noun, verb]

Sentence = [noun, verb]

Sentence = [verb, noun]

Finally,

- Ungrammatical sentences generated by the compiler.

sentence(Sentence, [], 0).

The compiler answers:

Sentence = [article, noun, verb, noun, article]

Sentence = [article, noun, verb, article]

Sentence = [noun, article, verb, article, noun]

Sentence = [noun, article, verb, noun, article]

Sentence = [noun, article, verb, noun]

...

## 5. Conclusions

In this contribution some elements in the possible design of a semi-sentence theory are sketched. In any case, the complexity of natural language means that the approach taken in this study is related to specific examples. We show how the notion of semi-grammaticality may be dealt with in formal grammar by using the notion of semi-string. Lastly, a computational perspective of the problem is given, showing how to implement the semi-grammatical rules in Prolog. Hence we can interview a Prolog compiler with regards to semi-grammatical English sentences.

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