

The Use of Punctuation Patterns in Machine Translation†

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The determination of sentence structure contributes greatly to the understanding of written texts, and represents, therefore, an element of considerable value in mechanical translation. The present study deals with the analysis of English language punctuation patterns and presents a sample program for an automatic punctuation analysis.

SINCE A MACHINE can easily recognize punctuation marks, it is pertinent to inquire how the pattern of punctuation marks within a sentence can be used to determine sentence structure. Such a study may result in the development of criteria which can be incorporated in a program for machine translation. While the present study deals with the analysis of English language punctuation patterns, a similar analysis can of course be made for the punctuation of any other language.

Nature of Punctuation

All languages exhibit certain basic differences among the sentences or clauses which may be constructed. These differences are intuitively recognized, even by children who know, for example, that a statement requires no response, while a question requires an oral response. Thus, sentences may be classified as declarative, imperative, interrogatory, or exclamatory. Another classification might distinguish among clauses¹ simple, compound,

or complex. One can intuitively postulate that punctuation marks are used in the written language to make these distinctions. Moreover, punctuation marks are also used to prevent ambiguity. Punctuation, then, is predominantly constructional, or grammatical, or logical. Because of this, certain invariances of punctuation patterns must exist. Indeed, most people will adhere to certain conventions and will strive to reduce ambiguity by the proper placement of punctuation within the sentences. In this sense, punctuation is part of the mechanics of writing, and insofar as it is, it will present a minimum of difficulties in the proposed analysis

On the other hand, punctuation also performs a non-logical, non-grammatical function, analogous to the part played in speech by intonation and pause and in writing by emphasis. In this respect, punctuation is an art rather than a part of the mechanics of writing. Clearly, this latter aspect makes it difficult to take certain patterns of punctuation marks and to draw conclusions from them about the sentence structure of the English language.

Fortunately, the situation may not be so troublesome as it might appear at first glance. Computing machines are not likely to be used to translate novels, poems and similar types of literary texts, but will probably be restricted to the translation of scientific texts. In view of this, a similar restriction can be imposed on the present analysis eliminating the more obvious cases of "psychological punctuation." Indeed, the more technical a text becomes, the

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1. Unless otherwise noted, technical terms of grammar or syntax will always be used in the conventional sense as defined in elementary textbooks.

more predominant the logical and constructional element in the punctuation. Deviations from the standard punctuation patterns should be only a minor consideration for technical texts.

Choice of Punctuation Marks

The present analysis will include all those punctuational patterns which are commonly found in normal technical language. Included marks are the period, comma, semi-colon, colon, question mark, exclamation point, quotation mark, parenthesis, and dash. Excluded will be the hyphen, apostrophe, asterisk, multiple dashes, dots, compound points (such as comma dash, colon dash, etc.), and oblique stroke. These punctuation marks are not included in the present analysis because their influence on the sentence structure of scientific texts is believed to be small, either because of the special nature of these punctuation marks, or because of their comparative infrequency in scientific texts.

Among the punctuation marks to be considered, such as colon, semi-colon, and so on, certain occurrences or patterns which are theoretically possible may also safely be disregarded. Examples are given below:

(1) A colon is sometimes used to denote interpolation, as in the following sentence:

"He was good: he himself thought he was very good: at extricating himself from difficult situations."

(2) A semi-colon is sometimes used to separate clauses or phrases having common dependence as in the following sentence:

"There is tears for his love; joy for his fortune; honor for his valor; and death for his ambition."

Such uses are not expected to occur in texts which are likely to be analyzed by machine.

There is another class of occurrences of punctuation marks which, although not infrequent in technical texts, must be disregarded in the analysis. This class includes all non-punctuational uses such as occur in mathematical expressions. These can be eliminated without excessive difficulty when the text is being transcribed for input into the machine by enclosing anything resembling a mathematical expression or equation between a pair of asterisks. Punctuation marks which appear between asterisks are then disregarded automatically during the analysis.

The major classes of other non-punctuational uses to be eliminated are given below:

(1) Periods are used following sets of capital letters which stand for names or titles. For example, M.P. stands for Member of Parliament, or N.Y. stands for New York.

(2) Periods are used following abbreviations or contractions, as in Dr., Mr., Maj. Gen., etc., i.e., and so on. These uses are fairly frequent in scientific texts.

(3) Periods are used in section or chapter headings, as in "1.1. Communication."

(4) Periods, commas, colons may also be used between digits in various capacities. Consider, for example, the following:

7:14:30 standing for 7 hours, 14 minutes, 30 seconds

12.50 standing for 12 1/2

12, 520 standing for 12 thousand 5 hundred and 20.

No general and attractive rule has been found for eliminating all of these situations satisfactorily. For case (1) it may be stipulated that the period following a single capital letter will be considered legitimate. If the period is followed by another capital letter and another period, then a special glossary must be consulted, and the periods must be disregarded. If the capital letters represent initials of proper names, they could not be found in the glossary; they would, however, have been eliminated from consideration by being enclosed between asterisks, as previously explained. A glossary must also be set up for the abbreviations mentioned under (2) above. Such glossaries should be fairly inclusive; in their construction, much help can be obtained from textbooks on punctuation, which usually contain long lists of these special words.

The punctuation marks in (3) and (4) can be eliminated by classifying them as arithmetic uses of punctuation. An expression such as 7:14:30 is then transmitted as *7:14:30*.

Additional work remains to be done if all non-punctuational uses of punctuation marks are to be eliminated. The rules specified here are sufficient, however, to dispose of the more troublesome cases.

Punctuation and Sentence Structure

Conventional textbooks on grammar generally classify punctuation marks in accordance with their function within a given sentence. Unfortunately, such a classification is difficult to

carry out by machine, since it requires the determination of syntactic or semantic characteristics of the related clauses or phrases. For this reason, it is convenient to let the punctuation patterns themselves serve as primary basis for classification in this study.² The classification is then independent of any relation which might exist between the punctuation and the surrounding text.

A sentence will be defined as a string of words between two punctuation marks of a certain type, and the parts of the sentence will be distinguished by their occurrences between two commas, or between a comma and a period, and so on. No consideration will be given to semantic characteristics, and syntactical relations will be used only when easily determinable. Instead, each word string between two punctuation marks will be treated as consisting of words belonging to specific word classes. These word classes will then be used in conjunction with the punctuation marks for analyzing the sentence. Usually a unique determination of the word class to which a word belongs will not be required; it is usually sufficient to store next to each word in the dictionary a code indicating the applicable word class or classes — noun, verb, adjective, etc. For present purposes the word classes are the conventional "parts of speech" of elementary grammar.

Proposed Analysis of Scientific Texts

Since the analysis of punctuation is to be done with the help of a computing machine, it is important to note a basic difference between the application of such a machine to the analysis of sentence structure, and the application of a computer to the solution of mathematical problems. When solving a mathematical problem, it is imperative that all possible special cases and exceptions be properly taken into consideration. A machine program which handles 95% of the cases which arise in the solution of a mathematical problem is not, in general, more useful than one which takes care of only 10% of the cases since neither program can be used to solve the problem. When analyzing sentence

structure with the objective of improving word-for-word translation, the situation is quite different. Indeed, a program which could determine certain structural elements of 95% of the sentences analyzed would be very valuable. The 5% whose structure could not be successfully analyzed by the program could still be treated by word-for-word translation, so long as all the words were stored in the dictionary. The present analysis was made with this philosophy in mind, and not with the intention of achieving perfect sentence-for-sentence translation.

It has been suggested already, that the technical texts to be analyzed exhibit certain very special characteristics, so far as punctuation is concerned. The patterns of punctuation found in the texts that were considered during this study were invariably of a simple nature. A text of ten pages which was examined in detail was found to contain only two semi-colons, a few parentheses, and a few dashes, in addition to the liberal use of commas and periods. The sentences were comparatively long, however, averaging over twenty-five words per sentence. In view of the comparative length of the sentences, the main objective has been to reduce the size of the string of words to be translated as a unit by taking into account the punctuation pattern occurring in the sentence. This reduction of each sentence into parts or substrings was accomplished by specifying criteria to indicate which words belonged to the same substring, and which did not.

Two main criteria were used for reducing a sentence into substrings: for certain strings of words, the initial and final punctuation marks were found to be sufficient; for the remaining strings it was necessary to determine the word class of the various words between two successive punctuation marks. Wherever possible, exact determination of word classes was avoided by basing the rules on more general criteria. Thus, if a substring did or did not contain a verb, or if it did or did not contain a present participle; it was often possible to make a decision without the necessity of determining uniquely the word class of each word in that substring.

In order to reduce possible ambiguities to a minimum, the use of a few lists of words was introduced. The lists were always kept small, so that they could be searched quickly and would use little storage space. For example, a list was made of the most frequent words of inclusion. If a word appeared on the list, it was

2. An attempt to use punctuation marks for the determination of certain types of grammatical clauses was made by V. A. Oswald, Jr., and Stuart L. Fletcher, Jr., "Proposals for the Mechanical Resolution of German Syntax Patterns," *Modern Language Forum* 36, No. 3-4, 1951.

treated in some specified manner, without the necessity of determining its word class. It was decided that any remaining ambiguities would be ignored by the machine.

The reduction of the length of the strings of words was achieved by two basic operations: separation and compression. The process of separation may be described by noting that under certain circumstances a string of words, S , can be broken down into substrings S_1, S_2, \dots, S_n , which may be treated separately so far as the translation process is concerned. Such substrings might be separate clauses within a given sentence, or parenthetical thoughts, or any other parts of the sentence which may be treated apart from the remaining words. A transformation T may then be defined, which transforms the sentence S into its transform $T(S)$. If T is translation, the $T(S)$ stands for a new sentence in the output language. In general, the transformation T is not a uniquely defined operation and there is no reason why the same T should apply to all the substrings S_i .

There are, however, circumstances where T consists of exactly the same operations for a set of substrings in a given sentence. Under these special circumstances the second basic process, compression, can be used. To apply compression to a set of substrings, it is first necessary to identify the substrings by noting the similarity in their formal structure; this, in turn, requires an exact determination of the word classes. However, once the substrings have been identified, the operator T need be determined for only one of the substrings, and can then be applied automatically to the others. Elements in an enumeration or a series, usually separated by commas in the sentence, are substrings of this type. Consider, as an example, the following string of words:

"Here we have a peach, an orange,
an apple, a pear and thirty, per-
haps thirty-one, grapes."

It may be noted first that the words "a peach, an orange, an apple, a pear" constitute a set of four indefinite articles each followed by a noun which is separated from the next article by a comma. Clearly, four substrings may be recognized, each consisting of one indefinite article and the noun immediately following it. As soon as a set of operations, T_i , has been specified which may be applied to one of the substrings, the same T_i may be applied to the other three substrings. It may be noted next that the words

"perhaps thirty-one" between the remaining two commas really express a parenthetical thought, which may be treated separately from the remaining parts of the sentence. The sentence may now be written as follows:

Here we have $\left. \begin{array}{l} \text{a peach} \\ \text{an orange} \\ \text{an apple} \\ \text{a pear} \end{array} \right\}$ and thirty
perhaps thirty-one grapes.

The punctuation, in this instance a set of five commas, was used to "separate" the parenthesis as indicated by a loop, and to "compress" the series as indicated by the brackets. In addition to the punctuation, the pattern of word classes in the sentence was also taken into account to assist in the appropriate classification of the substrings.

A set of specifications for a machine program is presented below. It is believed that any moderately experienced programmer can easily write a program for these specifications. An actual program has not been written, because it is felt that some of the rules could be improved, after further analysis. Specifically, some of the word lists require more extensive research. However, it is believed that the specifications as they stand, are capable of treating adequately about 95% of the word strings likely to be encountered in technical texts, and that they contain the main bulk of the results which can be hoped to be achieved by punctuation analysis. This, of course, requires experimental confirmation. No machine analysis was made. The sample text reproduced at the end of this article was analyzed by hand, care being taken to proceed with the analysis in the same step-by-step manner which would have been used, had the analysis been carried out by machine.

Program Specifications

(A) Step One

Consider one sentence at a time, that is, one string of words included between any two of the following: exclamation point, question mark, period. Mark the beginning and end of the sentence by two strokes and eliminate the corresponding punctuation mark.

Of course, before being eliminated, any punctuation mark must first be tested as to whether it might be used in some non-punctuational manner. If this is the case, it is merely passed over, and the next punctuation mark is considered.

(B) Step Two

Within every sentence mark the position of any pair of parentheses, dashes, or quotation marks by square brackets. When a dash (or parenthesis) is followed by another dash (or parenthesis) in the same sentence, the two will be considered a pair. Four dashes in the same sentence will be considered two pairs, and so on.

(C) Step Three

Mark the position of any semi-colon, colon, or single dash in the sentence by two strokes, except when these punctuation marks occur within a pair of parentheses, quotation marks, or dashes, in which case mark their position by one stroke. The strokes again replace the punctuation.

(D) Step Four

Consider the occurrence of commas within adjoining two-stroke marks; commas which are included in the brackets which have been set up in Step Two must be considered separately from those commas not within the brackets. If a series is detected, compress the terms of the series and mark by braces as shown in the example previously given.

Series use of the comma is defined as the occurrence in any sentence, of two or more terms of similar grammatical construction and common dependence, the terms of the series being separated by a comma. In a series of more than two terms, the last comma may or may not be followed by a conjunction. The terms of the series may be nouns, pronouns, adjectives, verbs, adverbs, prepositions, or combinations of the foregoing.

Some series will not be recognized because of small deviations in word patterns. Such substrings will be treated as parenthetical in Step Five without substantial loss in meaning. Examples are given below:

Good jobs are now plentiful, construction activity high, and employment at its peak.

Here the words "are now" or "is now" are not repeated in the second and third term of the series. These will, however, be treated as parenthetical by Step Five.

The strengthening of technical, college level, and advanced education is of paramount importance to the United States.

Here "college level" is used as an adjective and will not be recognized as such by the machine. The term will again be treated as parenthetical.

(E) Step Five

Consider the remaining commas within adjoining two-stroke marks, and mark by a loop any substring which may be considered a parenthesis and may therefore be treated without reference to the remaining words within the two-stroke marks. A parenthesis may be placed at the beginning of the string within adjoining two-stroke marks, if it starts with a two-stroke mark and ends with a comma; in the middle of the string if it starts with a comma and ends with a comma; and at the end of the string if it starts with a comma and ends with a two-stroke mark. Commas occurring within square brackets must be treated separately from those outside the square brackets. The parentheses will be marked in the following sequence:

(a) strings of words in the middle (that is, both preceded and followed by a comma) not containing any verb

(b) strings of words in the middle containing no verb form except a present participle (a verb form ending in "ing")

(c) strings of words in the middle containing no verb form except a past participle. (If past participles are not stored explicitly in the machine, this step may be omitted.)

(d) strings of words as defined in (a), (b), or (c) if they occur at the beginning or at the end of the substrings instead of occurring in the middle, except that any string of words at the beginning or at the end which adjoins a string already looped will not be looped, since it is already separated from the remainder of the substring

(e) strings of words which contain one of the verbs used to interrupt a narrative or quotation (say, tell, observe, suppose, interrupt, etc.) accompanied by any of the following: pronoun, noun, article, adjective, adverb, or any combination thereof. (This category is not believed important in technical texts and could be ignored.)

(f) strings of words containing no verb form other than an infinitive

(g) strings of words in the middle of a substring, starting with an adverbial clause or phrase (in order to do this, on the same day, etc.). If an exhaustive list of such adverbial clauses is not available, this category could also be ignored.

(h) strings of words in the middle starting with any of the following words of inclusion (words which refer to clauses after them):

after	since	wherever
although	that	whether
as	unless	which
because	what	whichever
before	whatever	while
how	when	who
if	whenever	whoever
in order that	where	why

(i) strings of words in the middle containing in juxtaposition two conjunctions, or adverb and conjunction, or conjunction and adverb (these are always subordinate clauses of some sort). Some of the more frequent occurrences are: whether if, that since, since even, then if, that if, even if, even while, even though, etc.

(F) Step Six

Consider the remaining commas, within adjoining two-stroke marks, (that is, those not already eliminated by brackets, braces, or loops) and mark the position of the comma by one stroke in the following order:

- strings of words starting with any simple coordinating conjunction (and, or, but, for, nor, neither)
- strings of words which fall under (e), (f), or (g) of Step Five, but which are at the beginning or at the end of the substring
- any comma not already eliminated should be replaced by one stroke.

In connection with Steps Five and Six, it should be mentioned that the machine program associated with each of the above steps is obvious from the description of the steps themselves, since these are based either on lists of words which must be searched or on certain easily recognizable word forms or classes.

Residual Problems

The program specifications outlined in the preceding section will properly recognize most punctuation patterns. There are, however, certain exceptions which are not covered as yet. Some examples are given below:

1. How could a comma used to replace missing words be properly recognized? For example, in the sentence

"I am fond of apples; he, of pears."

"he" and "of pears" would be recognized as parenthetical by Step Five.

2. How can series commas be recognized? Consider for example:

"The stooped, meticulously clad figure..."

Here "stooped" and "meticulously clad" ought to be recognized as two adjectives.

3. How can inversions be recognized? Consider

"..., the treatment of which may be stopped..."

Here the preposition and conjunction do not immediately follow the comma because of the inversion; however, the sentence ought to be treated as if preposition and conjunction did introduce the subordinate clause.

While these and other cases may not be included in the program specifications, the efficiency of the punctuation analysis is not greatly reduced, since constructions of this kind are relatively rare.

Conclusion

A text is analyzed in the next section to show the possibilities inherent in the proposed method. The sentences were almost invariably analyzed correctly. For some sentences no additional information was furnished by the analysis; for others, a correct analysis was dependent either on the correct determination of word classes or on the recognition of abbreviations and other non-punctuational uses of punctuation.

In spite of the difficulties, it is believed that the modest attempt made here at analyzing the structure of punctuation has been worth while. If a sufficient number of structural elements in the language are analyzed, and rules are specified for inclusion in an automatic translation program, it may eventually be possible to attain the accuracy of sentence-by-sentence translation.

Sample of Simulated Automatic Punctuation Analysis

The paragraph chosen for analysis is not from a scientific text but rather reproduces a conversation. It was chosen because no scientific text could be found which would exhibit a large enough variety of punctuation within a short paragraph to illustrate many of the steps described in the previous section. An immediate consequence of the non-technical character of the text is the fact that the sentences tend to be rather short, making for greater simplicity in the analysis. This should not, however, de-

tract from the fact that all the sentences in this text could be analyzed properly, despite a great variety of punctuational patterns. In further experiments with technical material long sentences were successfully analyzed.

The text is first given unaltered. Thereafter the text is reproduced after each of the six steps. Wherever the number of changes for any one step was very small, only the sentences which were actually changed are reproduced. The last copy of the text is broken down into substrings which start and end with a double stroke.

Text Before Simulated Automatic Analysis

Well, well, well! What are you* doing here, you old rascal?

Oh, nothing much.

Just looking around for what you can pick up, I suppose?

Tut, tut! Don't make me out to be a thief. I'm only an opportunist, after all, you know.

But a very unusual sort of opportunist: You don't merely grasp such opportunities as offer themselves to your remarkably observant eyes, Charles; you do a great deal — or so, at least, I suspect — to create the opportunities.

Why, Robert! The conversation is taking a strange turn. You began by almost insulting me; now you are paying me what is, in effect, a compliment — indeed, in its way, a very high compliment.

Darn it! That's not quite correct — I mean about the compliment — for although I admire your versatility, your resourcefulness, your adaptability —

Don't pile it on too thick, old man!

Don't interrupt! As I was saying, I admire these qualities; others I deplore. But you are quite right: we seem to be dropping into a fin de siècle persiflage and hatred of being earnest. However, I wanted to ask you for —

Sorry, old chap! Must tear myself away — my bus, you know.

Text After Step One

// Well, well, well // What are you doing here, you old rascal //

// Oh, nothing much //

// Just looking around for what you can pick up, I suppose //

* The words which are underlined were italicized in the original text.

// Tut, tut // Don't make me out to be a thief // I'm only an opportunist, after all, you know //

// But a very unusual sort of opportunist: You don't merely grasp such opportunities as offer themselves to your remarkably observant eyes, Charles; you do a great deal — or so, at least, I suspect — to create the opportunities //

// Why, Robert // The conversation is taking a strange turn // You began by almost insulting me; now you are paying me what is, in effect, a compliment — indeed, in its way, a very high compliment //

// Darn it // That's not quite correct — I mean about the compliment — for although I admire your versatility, your resourcefulness, your adaptability —

Don't pile it on too thick, old man //

// Don't interrupt // As I was saying, I admire these qualities; others I deplore // But you are quite right: we seem to be dropping into a fin de siècle persiflage and hatred of being earnest // However, I wanted to ask you for —

Sorry, old chap // Must tear myself away — my bus, you know //

Excerpt from Text after Step Two

//But a very unusual sort of opportunist: You don't merely grasp such opportunities as offer themselves to your remarkably observant eyes, Charles; you do a great deal [or so, at least, I suspect] to create the opportunities//

- - -

//That's not quite correct [I mean about the compliment] for although I admire your versatility, your resourcefulness, your adaptability —

Don't pile it on too thick, old man//

Text after Step Three

//Well, well, well / What are you doing here, you old rascal//

//Oh, nothing much //

//Just looking around for what you can pick up, I suppose //

//Tut, tut //Don't make me out to be a thief// I'm only an opportunist, after all, you know //

//But a very unusual sort of opportunist // You don't merely grasp such opportunities as offer themselves to your remarkably observant eyes, Charles // you do a great deal for so, at least, I suspect] to create the opportunities //

//Why, Robert // The conversation is taking a strange turn // You began by almost insulting me // now you are paying me what is, in effect, a compliment // indeed, in its way, a very high compliment //

//Darn it// That's not quite correct [I mean about the compliment] for although I admire your versatility, your resourcefulness, your adaptability//

// Don't pile it on too thick, old man//

//Don't interrupt//As I was saying, I admire these qualities // others I deplore // But you are quite right // we seem to be dropping into a fin de siecle persiflage and hatred of being earnest // However, I wanted to ask you for //

// Sorry, old chap // Must tear myself away // my bus, you know//

Excerpts from Text after Step Four

// { Well // well // well // What are you doing here, you old rascal //

- - -

//Darn it// That's not quite correct [I mean about the compliment] for although I admire

{ your versatility // your resourcefulness // your adaptability //

- - -

Text after Step Five

//Well {well {well // What are you doing here (you old rascal) // //Oh (nothing much) // //Just looking around for what you can pick up, I suppose // //Tut {tut // Don't make me out to be a thief // I'm only an opportunist (after all) you know // //But a very unusual sort of opportunist // You don't merely grasp such opportunities as offer themselves to your remarkably observant eyes (Charles) // you do a great deal [or so (at least) I suspect] to create the opportunities // //Why (Robert) // The conversation is taking a strange turn // You began by almost insulting me // now you are paying me what is (in effect)

a compliment // indeed (in its way) a very high compliment //

//Darn it// That's not quite correct [I mean about the compliment] for although I admire { your versatility { your resourcefulness { your adaptability //

// Don't pile it on too thick (old man) //

//Don't interrupt// As I was saying, I admire these qualities // others I deplore // But you are quite right // we seem to be dropping into a fin de siecle persiflage and hatred of being earnest //

//(However) I wanted to ask you for //

//(Sorry) (old chap) // Must tear myself away // (my bus) you know //

Excerpts from Text after Step Six

//Just looking around for what you can pick up / I suppose //

- - -

//Don't interrupt//As I was saying / I admire these qualities // others I deplore //

Final Text No. 1

String No.

- (1) { Well // well // well //
- (2) What are you doing here (you old rascal) //
- (3) (Oh) (nothing much) //
- (4) Just looking around for what you can pick up / I suppose //
- (5) { Tut // tut //
- (6) Don't make me out to be a thief //
- (7) I'm only an opportunist (after all) you know //
- (8) But a very unusual sort of opportunist //

- (9) You don't merely grasp such opportunities
as offer themselves to your remarkably
observant eyes (Charles)
- (10) you do a great deal [or so (at least) I
suspect] to create the opportunities
- (11) Why (Robert)
- (12) The conversation is taking a strange turn
- (13) You began by almost insulting me
- (14) Now you are paying me what is (in effect)
a compliment
- (15) indeed (in its way) a very high compliment
- (16) Darn it
- (17) That's not quite correct [I mean about the
compliment] for although I admire
 { your resourcefulness
 your versatility
 your adaptability
- (18) Don't pile it on too thick (old man)
- (19) Don't interrupt
- (20) As I was saying / I admire these qualities
- (21) others I deplore
- (22) But you are quite right
- (23) we seem to be dropping into a fin de siècle
persiflage and hatred of being earnest
- (24) (However) I wanted to ask you for
- (25) (Sorry) (old chap)
- (26) Must tear myself away
- (27) (my bus) you know