University of Pennsylvania

TRANSFORMATIONS AND DISCOURSE ANALYSIS PAPERS

28. Problems in the Computation of English Sentence Structure (Substring Analysis)

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1. String identifier

For purposes of computation, one of the most useful statements of a string grammar is that a sentence formula is decomposable into strings without residue. This means that if one member of a string can be identified in the sentence formula, then the other members must also be there. Suppose a particular string contains one symbol which is unique to that string, e.g. \( K_6 \) (whoever) is unique to the string \( K_6 \frac{\overbrace{\text{whoever reads Rimbaud}}}{V^+} \); if we can locate \( K_6 \) in a sentence formula, we can immediately impose a grammatical requirement, namely: \( V^+ \) must also be locateable in the sentence formula.

More broadly speaking, if each string has an identifying symbol we can separate the problem of identifying a string's occurrence in a sentence formula (discovering the fact of its occurrence), from that of computing its structure. It might be possible for example to identify which strings occur in a sentence formula by a quick scan for "string identifiers" (assuming each string has one) before analyzing the structure of the sentence. One might then choose to analyze particular portions of the sentence formula first, e.g. parts relatively free of ambiguity, or to use different methods for different portions.

Many strings in English have what might be called a string identifier (defined below), e.g. \( K_4 \) (what), while not unique to a single string, is a convenient
identifier of $K_4 V^+$ (what succeeds) and of $K_4 N V^-$ (what they said) because $K_4 V$ occurs only as a member of one of these two strings or in a question, whereas the other members of these two strings $V^+, N, V^-$, occur in many strings. Let us say that the symbol $X$ is an identifier of the string if $X$ is a member of $\alpha$ and $X$ has a much more limited distribution than other members of $\alpha$.

Do all the strings of English have identifiers, and if so, where is the identifier located in the string? A classification of the strings of English listed in TDAP 27 (pp. 37-41), about 100 in number, yields

a) the main body of strings - which do have identifiers;
b) object strings (about 30) - which have a modified type of identifier;
c) one symbol strings (about 10) - which serve as their own identifiers;
d) certain strings which begin with $N$ (13 in number) - which do not have identifiers.

a) All of the strings in what we have called the main body of strings have identifiers at a stateable distance from the leftmost element. We find that most strings have identifiers which are the leftmost symbol of the string, for example the string $\frac{4}{7} 2 N V$ (when it reaches us). Two groups of strings are exceptions; the "P K" strings in which the identifier is the second symbol from the left, and the "N P K" strings in which the identifier is the third symbol from the left. $^1$ We have:

$^1$But see section 2 below on recursion in P K and N P K strings.
2 Superscripts $P, +, -, e.g. V^P$, concern the computation of the object string, and are defined in section 2 below.
b) The object strings do not contain an identifier as defined above. However, the selection of object strings which can occur following a particular verb \( V_i \) in the sentence formula is a property of that verb, i.e. \( V_i \), which is not a member of the object strings which it specifies, functions like a string identifier in that it may be used to set up the requirements that certain other elements must also occur in the sentence formula. Like \( K_4 \), which is an identifier of more than one string, \( V_i \) may specify more than one possible object string, only one of which actually occurs; the requirement is that once \( V_i \) occurs, one of the possible object strings of \( V_i \) must occur.

c) One symbol strings are their own identifiers since in general they are not symbols which occur in other strings (except \( N \) of compound noun, \( N \) of apposition, discussed below). The 1 symbol strings are:
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Type of string</th>
<th>Word example</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>adjective</td>
<td>left adjunct of N or N's</td>
<td>free man</td>
</tr>
<tr>
<td>S</td>
<td>past participle</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td>freed man</td>
</tr>
<tr>
<td>G</td>
<td>verb with ing</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td>singing sparrow</td>
</tr>
<tr>
<td>Z</td>
<td>color word</td>
<td>&quot; &quot; &quot; &quot; &quot; replacement of N</td>
<td>red flowers, red is my favorite</td>
</tr>
<tr>
<td>Q</td>
<td>quantifier including numbers</td>
<td>&quot; &quot; &quot; &quot; &quot; replacement of N</td>
<td>some flowers, many protested</td>
</tr>
<tr>
<td>N</td>
<td>of cpd noun</td>
<td>&quot; &quot; &quot;</td>
<td>brick wall</td>
</tr>
<tr>
<td>N's</td>
<td>possessive</td>
<td>&quot; &quot; &quot;</td>
<td>boy's mother</td>
</tr>
<tr>
<td>T</td>
<td>article class</td>
<td>non-repeatable left element of N or N's</td>
<td>a chair</td>
</tr>
<tr>
<td>B</td>
<td>this, these (=T A) of N or N's</td>
<td>&quot; &quot; &quot;</td>
<td>this chair</td>
</tr>
<tr>
<td>R</td>
<td>pronoun</td>
<td>replacement of N</td>
<td>we</td>
</tr>
<tr>
<td>N</td>
<td>apposition</td>
<td>right adjunct of N</td>
<td>his father, a lawyer</td>
</tr>
<tr>
<td>&amp;</td>
<td>unary conj.</td>
<td>sentence adjunct</td>
<td>however</td>
</tr>
<tr>
<td>W</td>
<td>certain verb aux. left adjunct of V</td>
<td></td>
<td>will, may, can</td>
</tr>
<tr>
<td>D</td>
<td>adverb</td>
<td>left adjunct of A, S, G, Z, Q</td>
<td>partly free, lately freed, definitely coming, very red</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot; &quot; &quot; &quot; D</td>
<td>very few</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot; &quot; &quot; &quot; P</td>
<td>very thoroughly, completely unashamedly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot; &quot; &quot; &quot; V</td>
<td>completely under the covers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>right &quot; &quot; &quot; V</td>
<td>we definitely want to go</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sentence adjunct</td>
<td>we want strongly that he accept</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>generally, the items are found in groups</td>
</tr>
</tbody>
</table>
In addition there are subclassifications of some of the above which occur in definite positions, e.g.

Qₜ a subclass of quantifiers which can occur to the left of T (many the man)
Dₜ a subclass of adverbs which can occur to the left of T or Qₜ (just a man)
Aᵥ a subclass of adjectives which can occur to the right of of N (the people present) and various subclasses of T.

Particular words may have more than one classification, e.g. more D/Q (We liked him more, more girls) one Q/R (one chair broke, one would like to know), many Qₜ (The many persons, many the man) There is need for more work on the classification of articles and quantifiers and adverbs, including no and not.

d) A number of strings which begin with N do not have string identifiers as defined.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Type of String</th>
<th>Word Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td></td>
<td>the baseball scores</td>
</tr>
<tr>
<td>N(A {S {G</td>
<td>left portion of cpd N</td>
<td>a book buying spree</td>
</tr>
<tr>
<td>N G +</td>
<td>replacement strings of N</td>
<td>elephant hunting is ... people buying souvenirs is ...</td>
</tr>
<tr>
<td>N S +</td>
<td></td>
<td>his mission accomplished, he ... the room free, we ... the landlord out, the tenant ... the ship on its way, we ... the defendant a known SS man, the trial the book selling, the publishers</td>
</tr>
<tr>
<td>N A</td>
<td>sentence adjuncts based on N be⁺</td>
<td></td>
</tr>
<tr>
<td>N D₀</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N P N</td>
<td>sentence adjuncts</td>
<td></td>
</tr>
<tr>
<td>N N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N G⁺</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N (apposition)</td>
<td>right adjuncts of N</td>
<td></td>
</tr>
<tr>
<td>N V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N V⁺¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N V⁻²</td>
<td>sentence adjuncts</td>
<td></td>
</tr>
<tr>
<td>N⁻¹₄</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Only certain nouns, like reason, fact, can be adjoined by an N V⁺ string.
2 N⁻¹₄ is a class of verbs, such as think, suppose, which may have as object a complete sentence.
Since the symbol N occurs in many strings it is not by itself useful in announcing the presence of a particular N-containing string in the sentence formula. The same is true for most of the other symbols in the strings listed above. Thus these strings have no identifier as we have defined it. However, these strings are divided as to syntactic function, i.e. as to the positions they can occupy, and there are other restrictions which help to distinguish them from other sequences that include N. These strings discourage a computational scheme which first scans for string boundaries (using identifiers as cues) and then computes structure; they favor a scheme which brings a string in relation to other strings at the same time it identifies the string.

Summary: The main body of strings can be identified by a symbol which is either the leftmost element of the string or is in a stateable position relative to the leftmost symbol. The presence of an object string in the sentence formula is indicated by a verb which occurs to the left of the object string, in particular the verb of the string which includes the object string. Thus the great bulk of strings are left-oriented. The one symbol strings are neutral. There is also a group of about 15 strings which begin with N, the identification of which presents a problem in that they contain no symbol which marks them off from other strings.
2. Omission

2.1 Verb Object and Omission:

In analyzing a sentence formula it is necessary to associate an occurring object string with its verb. In TDAP 27 this was accomplished as follows:

Preliminary: We assume that the possible object strings of each English verb $V_i$ are listed in a dictionary prior to computation.

1. Object specification: Upon encountering $V_i$ in a sentence formula, copy its possible object strings from the dictionary into a register (called object register).

2. Comparison: Compare, symbol by symbol, each object string in the register with the sequence of symbols following $V_i$ in the sentence formula. If the symbols of an object string $O_i$ are identical with the symbols following $V_i$ in the sentence formula, the association of $O_i$ with $V_i$ is a possibly correct analysis.¹

NOTE: We say "possibly correct analysis" because $O_j$ (a shorter object string having the same symbols as the first portion of $O_i$) may also be a correct analysis and the decision as to whether the object of $V_i$ is $O_i$ or $O_j$ or both (permanent ambiguity) depends on the overall analysis of the sentence formula.

Depending on the string which contains a verb, the verb's object strings occur in slightly different form. In particular, if one adopts as a reference form of an object string, its form when its associated verb is the main verb

¹In an actual computational scheme, such as the one discussed in TDAP 27, there is provision for the occurrence of adjunct strings among the symbols of the object string.
of a sentence (i.e., of a center string), one finds that when the same verb occurs in certain non-center strings, the object string occurs with one less N. For example, the verb attribute has for object string (reference form)

\[ N P \text{ to } N \]  

\[ N_1 P \text{ to } N_2 \]

we might have: \( \frac{N_1 P}{P \text{ to } N_2} \) \( \frac{N_2}{\text{we attributed our success to chance; employing a which clause}} \)

which we attributed our success to... In each of the latter cases, where

\[ \frac{N_1 P}{P \text{ to } N_2} \]

the verb attribute occurs in a which string, we find following the verb attribute the object string \( N P \text{ to } N \) minus one \( N \).

One may ask: Suppose a verb object string contains more than one \( N \), such as the \( N P N \) object string of the verb attribute; can each \( N \) independently absent? The answer for most object strings is yes as the above example with attribute illustrates. We also find that when an object string contains a verb, the omission of \( N \) can be "passed along" to the object strings of the contained verb. E.g. in

The guide we told the children to ask the visitors to wait for was late.

we have an \( N V^- \) string (beginning with \( \text{we told} \)), but it is not the object string of \( \text{told} \) which occurs with one less \( N \) than in its reference form; rather we find a chain of three object strings after \( \text{told} \), the \( N \) being omitted from the last of the three.

---

1 We indicate the fact that an \( N \) is absent ("omitted") from the reference form of the object string of a \( V \) when that \( V \) occurs in a particular string by writing \( V^- \) for the \( V \) in the string. By contrast, \( V^+ \) stands for a verb having its object string in reference form. Thus the which string used in the example above is written \( K N V^- \) and the declarative center string is written \( N V^+ \).
Verb       Object String (Ref. form)       Omission
\( V_1 \) (told)  N to \( V_2^+ \) (children to ask)       "passed along"
\( V_2 \) (ask)  N to \( V_3^+ \) (visitors to wait)       "passed along"
\( V_3 \) (wait)  P N (for the guide)       P N → P

We can now formulate a rule for obtaining from the reference form of
the object strings of \( V_1 \), the form of these object strings when \( V_1 \) occurs as
the \( V^- \) of a string. Let the reference form of the object strings of \( V_1 \) be
in an object register. Let the "\( _- \)" of \( V^- \) indicate that the Rule of Omission
is to be applied.

\textbf{Rule of Omission:} 1. For each \( N_j \) in the object register, rewrite
the string which contains \( N_j \), leaving out \( N_j \).

2. For each object string \( O_k \) (in reference form)
which contains a verb \( V_k^+ \), add to the strings in the register a
copy of \( O_k \) with \( V_k^+ \) rewritten as \( V_k^- \).

Part I of the Rule governs the omission itself; part 2 provides for "passing
along" the omission.

\textbf{Example of the Application of the Rule of Omission}

We take a sample verb \( V_1 \) (told) in Column 1. We show the object
strings of \( V_1 \) in reference form, i.e. the contents of the Object Register
before the Rule of Omission (R. of O.) is applied, in column 2. We show
the results of applying R. of O., i.e. the contents of the Object Register
after R. of O. is applied in column 3. Columns 4 and 5 are devoted to word
illustrations of the forms in column 3 as follows: On each line, we let the verb *told* correspond to the $V^-$ of an $N V^-$ string, *we told*.... If the $N$-omission is according to part 1 of R. of O., a noun from the object string of *told* is omitted (column 4), e.g. in row 1, column 4 *children* is omitted from *we told* (the children) to invite the visitors. The omitted noun appears in front of the $N V^-$ string. If the $N$-omission is according to part 2 of R. of O. it means the signal for omission has been "passed along" to a verb, e.g. *invite*, contained in an object string of *told* (column 5), e.g. in row 1, column 5, *visitors* is omitted from *we told the children to invite the visitors*. The place of the omitted $N$ is indicated by ( ).

<table>
<thead>
<tr>
<th>Verb</th>
<th>Object Strings (contents of object register before rule is applied)</th>
<th>Rule of Omission applied (contents of Object Register after Rule is applied)</th>
<th>Word Example Part 1 of Rule of Omission</th>
<th>Word Example Part 2 of Rule of Omission</th>
</tr>
</thead>
<tbody>
<tr>
<td>told</td>
<td>$N$ to $V^+$ to $V^-$</td>
<td></td>
<td>the children we told ( ) to invite</td>
<td>the visitors we told the children to invite ( )...</td>
</tr>
<tr>
<td></td>
<td>$N P$ of $N$</td>
<td></td>
<td>the adventures we told him of ( )...</td>
<td>the adventures we told him about ( )...</td>
</tr>
<tr>
<td></td>
<td>$N P$ of $N$</td>
<td></td>
<td>the man we told ( ) of our adventures</td>
<td>the man we told ( ) about our adventures</td>
</tr>
<tr>
<td></td>
<td>$N P$ about $N$</td>
<td></td>
<td>the adventures we told him about ( )</td>
<td>the man we told ( ) the tale</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N N^8$</td>
<td>$N$</td>
<td></td>
<td>the tale we told ( ) the man</td>
<td></td>
</tr>
<tr>
<td>$N^8$</td>
<td>$\varphi$</td>
<td></td>
<td>the man we told ( ) the tale</td>
<td></td>
</tr>
<tr>
<td>$N$</td>
<td>$\varphi$</td>
<td></td>
<td>the man we told ( )</td>
<td></td>
</tr>
<tr>
<td>$N^8$</td>
<td>$\varphi$</td>
<td></td>
<td>the tale we told ( )</td>
<td></td>
</tr>
</tbody>
</table>
At the beginning of this section we described a procedure for computing object strings in their reference form, i.e. objects of $V^+$. Now suppose $V_i$ occurs in the $V^-$ position of a string, e.g. as the verb in the string $N V^-$, we can adapt the procedure for computing the object of $V^+$ for use with objects of $V^-$ by adding to step 1 (specification) the following:

Apply the Rule of Omission to the object strings in the object register.

Table 1 below shows the application of the Rule of Omission to the objects strings of English. Exceptions to the rule are noted by footnotes at the end. Columns 1, 2, 3 of the table are similar to columns 2, 4, 5 respectively, of the Example above. In addition, in column 1 of Table 1, the N-to-be-omitted is underlined. In some cases, another string in place of $N V^-$ is used in constructing the word illustrations of columns 2 and 3.

**TABLE 1**

Omission in Verb Object Strings

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Object String</strong></td>
<td><strong>Example of N-omission</strong></td>
<td><strong>Example of N-omission passed along 1 step</strong></td>
</tr>
<tr>
<td>$N$</td>
<td>people whom we found ( )</td>
<td></td>
</tr>
<tr>
<td>$N P_1$</td>
<td>the facts we correlate ($N P_1$)</td>
<td></td>
</tr>
<tr>
<td>$N \text{ and } N^1$</td>
<td>this and that we correlate ($N &amp; N$)</td>
<td></td>
</tr>
<tr>
<td>$N \text{ with } N^1$</td>
<td>the $x$ we correlate ($N^1$) with $y$; the $y$ we correlate $x$ with ($N^2$)</td>
<td></td>
</tr>
<tr>
<td>$V^+_n$</td>
<td>the dream he dreamt ( )</td>
<td></td>
</tr>
<tr>
<td>$N \text{ in } N$</td>
<td>the book we gave him ( )</td>
<td></td>
</tr>
<tr>
<td>$N P \text{ to } N$</td>
<td>the book we gave ($N^1$) to him</td>
<td></td>
</tr>
<tr>
<td>$P N$</td>
<td>the man we rely on ( )</td>
<td></td>
</tr>
<tr>
<td>$N D_p$</td>
<td>the game we broke ( ) up</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Object String</strong>&lt;br&gt;(ref. form)</td>
<td><strong>Example of N-omission</strong></td>
<td><strong>Example of N-omission passed along 1 step</strong></td>
</tr>
<tr>
<td>$D_p ; N$</td>
<td>the game we broke up ( )</td>
<td>stories we like reading ( )</td>
</tr>
<tr>
<td>$G^+$</td>
<td></td>
<td>the passage he refrained from quoting ( )</td>
</tr>
<tr>
<td>$P_i ; G^+$ to $V_o^+$</td>
<td>the consequences it is possible ( ) will result</td>
<td>the children we want to teach ( )</td>
</tr>
<tr>
<td><em>(it is) $A_8 ; H ; N ; V^{+2,4}$</em></td>
<td>the person for whom it is possible (for N) to speak like that</td>
<td>the course it is possible that none will take ( )</td>
</tr>
<tr>
<td><em>(it is) $A_8$ for $N$ to $V^{+3,4}$</em></td>
<td></td>
<td>the cake it is possible for me to bake ( )</td>
</tr>
<tr>
<td><em>(it is) $A_8$ to $V_o^+ + 4$</em></td>
<td></td>
<td>the music it is possible to compose ( )</td>
</tr>
<tr>
<td>$A ; P ; G^+$</td>
<td>the machine we made ( ) work</td>
<td>The music he is good at composing ( )</td>
</tr>
<tr>
<td>$N ; V^+$</td>
<td>the experiment we thought ( ) worked</td>
<td>the load we made the horse carry ( )</td>
</tr>
<tr>
<td><em>(H) $N ; V^{+12}$</em></td>
<td>the book we insisted ( ) appear</td>
<td>the flowers we hoped that he would plant ( )</td>
</tr>
<tr>
<td><em>(H) $N ; V^{+21}$</em></td>
<td></td>
<td>the flowers we preferred he plant ( )</td>
</tr>
<tr>
<td>$N ; A$</td>
<td>the man we thought ( ) wise</td>
<td></td>
</tr>
<tr>
<td>$N ; D_2$</td>
<td>the man we thought ( ) here</td>
<td></td>
</tr>
<tr>
<td>$N ; N^5$</td>
<td>the man we thought ( ) an Englishman</td>
<td></td>
</tr>
<tr>
<td>$N ; P ; N$</td>
<td>the man we thought ($N_1$) in Philadelphia</td>
<td>the city we thought the man in ($N_1$)</td>
</tr>
</tbody>
</table>
TABLE 1 (continued)

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object String (ref. form)</td>
<td>Example of N-omission</td>
<td>Example of N-omission passed along 1 step</td>
</tr>
<tr>
<td>N as $D_2$</td>
<td>the man we consider ( ) as here</td>
<td>the battles we consider him as having won ( )</td>
</tr>
<tr>
<td>N as $G^+$</td>
<td>the man we consider ( ) as being fair</td>
<td></td>
</tr>
<tr>
<td>N as $N^5$</td>
<td>the man we consider ( ) as candidate</td>
<td></td>
</tr>
<tr>
<td>N $G^+$</td>
<td>the classes we opposed ( ) starting at 8 A.M.</td>
<td>the classes which we oppose starting ( ) at 8</td>
</tr>
<tr>
<td>N H N $V^+$</td>
<td>the man we told (N$_1$) a risk would result</td>
<td>the man we told them nothing could stop ( )</td>
</tr>
<tr>
<td></td>
<td>the riot we told the man (N$_2$) would result</td>
<td>certain rules we restrained them from breaking ( )</td>
</tr>
<tr>
<td>N P$_1$ $G^+$</td>
<td>the man we restrained ( ) from going</td>
<td>the conditions we want the plans to alleviate ( )</td>
</tr>
<tr>
<td>N to $V^+_o$</td>
<td>the plans we want ( ) to succeed</td>
<td></td>
</tr>
<tr>
<td>N H N should $V^+$</td>
<td>the man we told ( ) that he should go home</td>
<td>the load we prefer for him to carry ( )</td>
</tr>
<tr>
<td>for N to $V^+_o$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P N H N $V^+_o$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A P N$^8$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$N and N are to be treated as a single N

$^2$H is dropped whenever the adjacent N is omitted from the object string.

$^3$For = must be moved along with the N

$^4$This object string is a possible object of the verb be only when the subject of be is it.

$^5$the second N is not omittable.

$^6$The N following for is not omittable.

$^7$There are no omissions from the object string P N H N $V^+_o$ e.g. ask of him that he grease the car.

$^8$The N is not omittable from A P N of the type quick to anger.
2.2 A more general picture of "N-omission"

Consider:

The book exists
He found the book
He selected the title for the book

The book which exists
The book which he found
The book which he selected the title for

It is apparent that a similar relation exists between the left and right utterance of each pair. The sentence on the left appears on the right following the word which with the book omitted. If we compare the grammatical role of the book in each of the three sentences on the left we find that it is respectively: the subject, the object of the verb, the noun of a prepositional phrase adjoined to the object of the verb.

Up until now we have considered N-omission only of the type found in the second example, namely, omission of N from the object. The reason is that we can state the structure of strings with other kinds of N-omission in advance of computation without reference to what occurs in a particular sentence formula, whereas in omission of N from the verb object we must wait until a particular verb is encountered in the sentence formula in order to obtain the structures from which to omit an N. Thus, if we want to maximize the stored information in place of deriving expected structures as we go along, we separate the object case from all the others, and define "N-omission" operationally only in relation to strings which contain V-, as was done in 2.1 above.
But for some purposes, it is worthwhile to consider N- omission in a broader sense, covering all three cases above, and others, regardless of how the information is arranged for a string computation. For one thing, it is helpful in understanding how the many strings listed in a string grammar derive from a few basic forms; in particular, in the analysis used here, from a single N V^+ center string. Further, when arranged in tabular form, it is easier to check how much of English is covered and in what way by the string grammar.

Therefore, we add below, a table of strings which involve N- omission (in the broader sense) indicating the grammatical role of the omitted N with reference to an N V^+ string and its adjuncts. As an example of how to read the table consider the row which begins with K_3 which. The check in the intersection of the K_3 row with the V^+ column indicates that the string K_3 V^+ exists in English. A word example of K_3 V^+ is obtained by reading the word which, followed by the word example V^+, exists, i.e. which exists. Similarly, the check in the intersection of K_3 row with the N V^- column indicates that the string K_3 N V^- exists in English and the example is which he found. Each column specifies the source of the N- omission, so that the original N V^+ with its adjuncts can be reconstructed. E.g. the column V^+ was obtained by omitting the subject N from N V^+; if we supply a noun (the book) in subject position, we obtain the book exists.
### TABLE 2a

Omission of N in Strings

<table>
<thead>
<tr>
<th>Omission of:</th>
<th>Subject N</th>
<th>N of Object</th>
<th>N of PN; PN adjunct of V or of object N</th>
<th>Adjective of subject N</th>
<th>Adjective of object N</th>
<th>Adjective of PN of VERB or of object N</th>
</tr>
</thead>
<tbody>
<tr>
<td>String (minus string identifier):</td>
<td>V⁺ e.g. exists</td>
<td>N V⁻ e.g. he found</td>
<td>N V⁺ P e.g. he selected the title for</td>
<td>N V⁺ e.g. estate survives</td>
<td>N N V e.g. house they choose</td>
<td>N N V⁺ P e.g. house we held the meeting in</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>String identifier</th>
<th>(\emptyset)</th>
<th>H (that)</th>
<th>(K_1) (who)</th>
<th>(K_2) (whom)</th>
<th>(K_3) (which)</th>
<th>(K_4) (what)</th>
<th>(K_5) (whose)</th>
<th>(K_6) (whoever)</th>
<th>(K_7) (whomever)</th>
<th>(K_8) (whichever)</th>
<th>(K_9) (whatever)</th>
<th>(K_{10}) (whosoever)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\emptyset)</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H (that)</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_1) (who)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_2) (whom)</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_3) (which)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_4) (what)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_5) (whose)</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_6) (whoever)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_7) (whomever)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>(K_8) (whichever)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_9) (whatever)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K_{10}) (whosoever)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 2b

<table>
<thead>
<tr>
<th>Omission of:</th>
<th>PN adjoined to subject N</th>
<th>PN adjoined to object N</th>
<th>Adjective of N of PN adjoined to subject N</th>
<th>Adjective of N of PN adjoined to N of object</th>
</tr>
</thead>
<tbody>
<tr>
<td>String (minus initial portion through K)</td>
<td>$v^+$ e.g. exists</td>
<td>$n v^-$ e.g. he found</td>
<td>$n v^+$ e.g. estate survives</td>
<td>$n n v^-$ e.g. house they chose</td>
</tr>
</tbody>
</table>

Initial portion of string

- - - - - - -

$NP_{K_2}$

- e.g. an heir of whom

$NP_{K_3}$

- e.g. an heir of which

$NP_{K_4}$

- e.g. an heir of whose

Omission may be "passed along" to adjuncts included in a K-string, particularly PN adjuncts. Thus column 4 and 7 of Table 2a and all of Table 2b show only the first of a set of recursively extendable forms with omission.

For example, in Table 2a:

**column 4 extended**

$K_3 N v^+ P$

which he selected the jacket for

$K_3 N v^+ P N P$

which he selected the picture on the jacket for

$K_3 N v^+ P N P N P$

which he selected the colors in the picture on the jacket for

**column 7 extended (more awkward)**

$K_5 N n v^+ P$

whose house we held the meeting in

$K_5 N n v^+ P N P$

whose " " " " " " the foyer of
Examples from table 2b are:

Column 3 extended

\[ N P K_3 N V^- \] (the estate), an heir of which he found
\[ N P N P K_3 N V^- \] " " , a grandson of an heir of which he found
column 4 extended

\[ N P K_5 N V^+ \] (the man), an heir of whose estate survives
\[ N P N P K_5 N V^+ \] " " , a grandson of an heir of whose estate survives

In all cases the omission is from the last \( P N \) of a string of \( P N s \).

The \( K \) strings in columns 4 and 7 of Table 2a (not \( \phi, H \)) may also appear with \( P \) preceding \( K \) instead of \( P \) at the end of the string, e.g.

\[ P K_3 N V^+ \] (for which he selected a title). This is one source of \( P K \) strings.

The other source of \( P K \) strings is columns 3 and 6 when the object string from which \( N \) is to be omitted contains \( P N \). In that case, \( P N \) is omitted from the reference form of the object string and the \( P \) "is moved" in front of \( K \), e.g.

\[ P K_3 N V^- \] (on whom he relied).\(^1\)

In the case of omission of an adjective (more properly, adjectival element, see Section 4 below), the adjectival element is often \( N ' s \) (John's).

Should the \( N ' s \) in question have its own adjectives, these are carried along with the \( N ' s \); they are omitted from the string and appear in front of the \( K \) with the \( N \).

\(^1\)In TDAP 27 an instruction OBJ P gives the procedure for computing the object of the verb \( (V^P) \) of a PK string. It is similar to the procedure described in 2.1 above for computing the object of \( V^- \). But before adjusting the object strings in the object register OBJ P institutes a comparison of the head \( P \) (PK) with the Ps in the object register to determine whether the object string is of the form of columns 4 and 7 or of the form of columns 3 and 6.
E.g., $N_1$'s $N_2$'s $N_3$ (The man's hats' feather) $\rightarrow$

\[ \begin{array}{c}
1 \\
2 \\
3 
\end{array} \]

\[ \begin{array}{c}
N_1 \\
K_5 \\
N_2 \end{array} \]

a) $N_1 K_5 N_2$'s $N_3$ ... (The man whose hat's feather ...)

[Here there are no adjectives of $N_1$ to be carried.]

b) $N_1$'s $N_2 K_5 N_3$ ... (The man's hat whose feather ...)

[The adjective $N_2$ is carried along.]

3. **Conjunctions**

When the element $C$ (and, or, but\(^1\)) occurs in the sentence formula, we can find a structure to the left of $C$ ($\alpha$) and one to the right of $C$ ($\alpha'$) which bear to each other a certain relation which we will call **C-equivalence** ($\alpha C \alpha$). This relation is first stated for particular cases and then a general form for C-equivalences in strings is given.

3.1 **C-Equivalence of left adjuncts of $N$:** As a preliminary, we name the main left adjuncts of $N$. These are:

---

\(^1\)The element than (preceded in the sentence formula by more or less or rather or worse or -er) and the element as (preceded in the sentence formula by as) can be classed in $C$. Discussion of these is temporarily deferred.
Pre-article quantifier $Q_t$
  e.g. many

Article $T$

$T_1$ a
$T_2$ the
$T_3$ some
$T_4$ either, neither

B (this, that, these, those)

Quantifier $Q$
  e.g. more, many, few, several

Adjectival element

$$\overline{A} \{ A, G, S \}$$

$e.g.$ young
gathering
given, determined

$Z$
  e.g. blue

$N$'s
  e.g. John's, his

Left portion of compound noun

$N$
  e.g. telephone in telephone repairman

$N \overline{A}$
  e.g. friction generating to friction generating elements

When $C$ occurs in a sentence formula immediately following a left adjunct of $N$ -- call it $X$ --, the most common $C$-equivalence is $X \ C \ X'$, i.e. two elements of the same class conjoined by $C$. $X \ C \ X'$ will be followed by an $N$ of which both $X$'s are adjuncts, with $X$ and $X'$ either grouped together into one adjunct or adjoined independently (see below); other adjuncts may intervene between $X \ C \ X'$ and $N$. Explicitly, thwn $C$ occurs among left adjuncts of $N$, we have the $C$-equivalences:

1

1In the examples, the words corresponding to the $C$-equivalence are underlined.
(1)  B C B'  and  this or but (not)  that free element

(2)  Q C Q'  more and more people

(3)  \( \bar{A} C \bar{A}' \)  young and talented candidates

(4)  Z C Z'  blue or green walls

(5)  N's C N's'  John's or my considered opinion

(6)  N C N'  telephone and telegraph repairmen

(7)  \( \bar{N} \bar{A} C N\bar{A}' \)  tin plated and air free vessel

Let \( X, Y \) represent two different left adjuncts of \( N \); C-equivalences of the form \( X C Y' \) occur more rarely than \( X C X' \). A few examples of varying likelihood of occurrence are:

\[
\begin{align*}
Z C \bar{A}' & \quad \text{blue and fresh sky} \\
Q C \bar{A}' & \quad \text{more and good cooks} \\
N's C Z' & \quad \text{John's and blue wall} \\
N's C \bar{A}' & \quad \text{John's but false opinion} \\
N C N\bar{A}' & \quad \text{glass and air free vessel} \\
\bar{N} \bar{A} C N' & \quad \text{mountain climbing and pack mules.}
\end{align*}
\]

\( X C Y' \) is more likely when \( X \) and \( Y \) are 'neighbors' in the ordered list of left adjuncts given at the beginning of the section, e.g.

\[
\begin{align*}
\bar{A} C Z' & \quad \text{cloudy and grey sky} \\
Z C \bar{A}' & \quad \text{grey and cloudy sky}
\end{align*}
\]

are more likely than

\[
\begin{align*}
Q C Z' & \quad \text{several and grey clouds} \\
Z C Q' & \quad \text{grey and several clouds}
\end{align*}
\]
Also \( X \in Y' \) is more likely when \( Y \) is preceded by an adjunct, e.g.

\[
\begin{align*}
    Z & \quad C \quad \overline{A'} & \quad \text{a blue and remarkably fresh sky} \\
    Q & \quad C \quad \overline{A'} & \quad \text{more and, in my opinion, good cooks are needed.}
\end{align*}
\]

(Compare with \text{blue and fresh sky, more and good cooks}).

The last two examples also show that \( C \)-equivalent structures \( \alpha \) and \( \alpha' \) are not always contiguous with \( C \); for instance, the structure immediately following \( C \) may be a left adjunct of \( \alpha' \) or a sentence adjunct. The sole left adjunct of left adjuncts of \( N \) is \( D \) (adverb), so that when the element after \( C \) is \( D \), either \( \alpha \in C \in \alpha' = D \quad C \quad D' \) or else the \( D \) which follows \( C \) is a left adjunct of the \( \alpha' \) structure, e.g.

\[
(8) \quad \begin{align*}
    D & \quad C \quad D' & \quad \text{discernably or allegedly studious members of the class} \\
    A & \quad C \quad A' & \quad \text{lively and allegedly studious members of the class}
\end{align*}
\]

An ambiguity arises when it is \( \alpha' \), the left member of the \( C \)-equivalence, which has left adjunct \( D \). Then we do not know whether \( D \) is an adjunct of \( \alpha \) alone or of both \( \alpha \) and \( \alpha' \), e.g. \text{very} in

\[
\begin{align*}
    D & \quad \overline{A} \quad C \quad A & \quad \text{very lively and studious members of the class.}
\end{align*}
\]

In general, if \( \alpha \) and \( \alpha' \) can both have a particular left adjunct, and that adjunct occurs to the left of \( \alpha \) in the sentence formula, we do not know whether to associate the adjunct with \( \alpha \) or with \( \alpha \) and \( \alpha' \). This type of structurally undecidable ambiguity is also found where right adjuncts of \( \alpha \) or \( \alpha' \) occur to the right of \( \alpha' \), e.g. \text{yesterday} in

\[
\begin{align*}
    \text{The experiment which we started and they finished yesterday.}
\end{align*}
\]
Another ambiguity concerns whether $\alpha \cap \alpha'$ should be grouped as a unit or not, e.g.

Telephone and telegraph repairmen

$$(\quad) = \text{men who repair both telephones and telegraph equipment.}$$

$$(\quad) (\quad) = \text{a group, some of whom are telephone repairmen and some telegraph repairmen.}$$

Sometimes the subclassification of the Ns is such as to rule out a grouping, e.g. there is only one grouping for: **electrician and telephone repairman**.

When a sequence of left adjuncts of N begins with T, it is possible to obtain C-equivalent structures $\alpha, \alpha'$ which are sequences of several elements, each sequence beginning with (the same) T, (But not T C T) e.g.

$$\text{T A C T A} \quad \text{a large and a publicly owned garden}$$

although more frequently the second occurrence of the article is absent. Equivalences such as T A C T A where $\alpha$ includes more than one symbol as well as all the other equivalence of left adjuncts of $N_1$ are obtained automatically from the general form of Type 1 C-equivalence of strings (3.4, 3.5 below) by considering the nounphrase headed by N as a string.

3.2 **C-equivalences of Ns and N-replacement Strings**

When C occurs in the sentence formula after N (where N is not a left portion of a compound N) we have the C-equivalence:

$$(1) \quad N C N' \quad \text{dawn and twilight}$$

There may be left adjuncts of $N'$ occurring between C and $N'$, e.g.
chocolate and hard candies. There are several questions as to the grouping of N and N' and their adjuncts. Sometimes N' can stand as a separately grouped element (with or without adjuncts), e.g.

A (N) C (N') mechanical toys and television;
sometimes it must be grouped with N,

(a) because N' is a count-noun and requires the article which occurs to the left of N, e.g.

T (N C N) a table and chair

(b) because the two Ns have a particular relation, e.g.

A (N C N) the mixed butter and sugar

According to Vendler, there is an ordered subclassification of adjectives (extendable to all left adjuncts of N), such that if a member of each subclass occurs in a sequence, the order of the sequence is fixed. If any subclass is not represented in the sequence its "slot" is empty. Let A_i represent ordered subclasses of left adjuncts of N, i increasing from left to right.

Then a C-equivalence is:

(2) A_i ...N C A_i ...N'

e.g. blue Venetian glass and Wedgewood pottery

Left adjuncts of N occurring to the left of A_i ...N may adjoin N or both N and N', e.g. in the above example, blue, which is a lower order subclass of adjectives than either Venetian or Wedgewood, might be adjoined to glass or to both glass and pottery, though some speakers may not accept the latter grouping.

If the element to the left of A_i ...N is an article, it most often adjoins both

1Cf. Zeno Vendler, "Order of Adjectives."

2Possibly a table and chair is T N C (T) N where the second occurrence of T is in zeroed form. This would have to be demonstrated by some test.
N and N', e.g. the Venetian glass and Wedgewood pottery. There would seem to be a restriction on C-equivalence involving N, to the effect that the two entities: N-and-all-its-adjuncts, N'-and-all-its-adjuncts, should be equally specific; this is difficult to state but may be worth investigating. E.g. not early dawn and the twilight, perhaps not dawn and late twilight.

Among the replacement strings of N there are two groups: (1) verb containing strings, like \( K_4 N V^- \) (what he said) and (2) non-verb containing strings, namely

- \( R \) pronoun e.g. we are here
- \( Q \)
- \( Q_t \) some classes as left adjuncts of N
- \( T_4 \)
- \( T_2 \overline{A} \)

A verb-containing replacement string may contain a C-equivalence (what he and the others said); the C-equivalences which apply are those stated for verb-containing strings in general with the one restriction that the scope of the equivalence is determined by the position of the replaced N (see 3.5 and C-equivalences of strings, below).

With reference to the non-verb-containing replacement strings, a C can only occur at the end of the string since the strings are one symbol in length except for \( T_2 \overline{A} \), and \( T_2 C T_2 \) does not occur. Let \([ rn ]\) stand for any replacement string of N; when C occurs at the end of a replacement string we have the C-equivalences:
(3) \( N \quad C \quad [\text{rn}]' \quad \text{The man and what he stands for} \\
(4) \quad [\text{rn}] \quad C \quad \text{N'} \quad \text{We and others of our opinion} \\
(5) \quad [\text{rn}] \quad C \quad [\text{rn}]' \quad \text{The following and whatever is based on it} \\

In the first equivalence there is no ambiguity as to the associativity of left 
adjuncts of N since replacement strings do not have left adjuncts. In the 
second equivalence, right adjuncts of N (not separated by a comma) are 
most often associated with N.

3.3 C-Equivalences of the verb phrase

The C-equivalences of verbal elements requires considering the possible 
object strings of a verb as well as the verb form itself. The verb part can 
occur in various forms:

\[ V_t \quad \text{(tense-marked verb)} \quad \text{e.g. goes} \]
\[ W \quad V \quad \phi \quad \text{(V \phi verb with no tense mark)} \]
\[ W \quad \text{auxiliaries, e.g. can, will, should, may) e.g. will go} \]
\[ \text{have V-en e.g. has gone} \]
\[ \text{be V-ing e.g. is going} \]
\[ \text{do V \phi e.g. did go} \]

The elements have, be, do themselves occur in one of the above forms. In 
particular, each may occur in any form written above it in the listing above 
extcept do which is always \( V_t \), e.g. will have gone, may have been going 
(but not are having gone and not have done go). We will name the verb in its
various forms \( wV \) where for each form of \( V \) listed above \( w \) has the value of the element preceding \( V \), i.e. \( w = \phi \) (before \( V_L \)), \( w = W \) or \( \underline{do} \) (before \( V\phi \)); \( w = \underline{have} \) (before \( V\text{-en} \)); \( w = \underline{be} \) (before \( V\text{-ing} \)).

We first note several C-equivalences involving \( W \)

\[
(1) \quad W \; C \; W' \quad \text{e.g. we can and should succeed}
\]

Sometimes \( W \) is C-equivalence with a verb construction, \( V \ldots \phi \), which is followed by \( V\phi \). Note: In general, if each member of a C-equivalence requires that a particular element (the same element for each member) occur somewhere to the right of it in the sentence formula, we will show the common required element in \( \{ \ldots \} \) to the right of the equivalences.

\[
(2) \quad W \; C \; V' \ldots \phi \quad \{V\phi\} \quad \text{e.g. They could but are not likely to perform his music}
\]

\[
(3) \quad V' \ldots \phi \; C \; W' \quad \{V\phi\} \quad \text{e.g. We want to and can succeed}
\]

Two \( wV \), or two \( V\text{-ing} (G) \), or two \( V\text{-en} (S) \), are potentially C-equivalent if among the possible object strings of each \( V \) of the pair (as given, say, in a grammatical dictionary) there is a common member. For example, if \( V_N = \) a verb which may have \( N \) for object, a C-equivalence is:

\[
\{wV_N \; C \; wV_N', \; \{N\} \quad \text{e.g. He produced and directed a film}
\]

More generally if \( \gamma \) stands for the subclassification of verbs which can take as object string

\[
(4) \quad wV_\gamma \; C \; wV_\gamma' \quad \{\gamma\}
\]

If \( wV_\gamma \) is in a string which calls for omission of \( N \) from the object string of \( V \), i.e. a string containing \( V^- \), then \( V_\gamma' \) must also omit an \( N \) from its object string, e.g.

The book which we requested and bought.
3.4 C-Equivalences of Strings

We consider a generalized formula for a string $\beta$

$$\beta = K N_s w V^+_i O^-_i$$

where $K$ = a string identifier and any other elements of the string which precede $N_s$, $N_s$ = subject N, $wV$ = verb form as defined in 3.3 above, $V_i$ = a particular English verb, $O^-_i$ = a possible object string of $V_i$. The verb may call for an object string in reference form ($V^+$) or for an object string with N-omission ($V^-$). In particular strings, one or more elements may not be present, e.g. The center string $N_s wV^+_i O^-_i$ has no identifier, the who-string $K_s wV^+_i O^-_i$ has no $N_s$, etc. For these cases, rewrite the equivalences stated below without the general element not present in the particular string and drop duplicates.

Suppose C occurs in the sentence formula immediately following $O^-_i$. We have the (type I) C-equivalences:

\[\text{\footnote{A more general formulation of Type I C-Equivalence for strings is: Let } \beta \text{ stand for a string whose elements are from left to right } b_1, b_2 \ldots b_i, \ldots b_n. \text{ Let } i^\beta_j \text{ stand for the elements of } \beta, b_i \text{ through } b_j \text{ inclusive. Suppose in a sentence formula, } C \text{ occurs immediately following the } m^{th} \text{ element of } \beta, \text{ the type I } C \text{-equivalences are:}

i^\beta_m C \left\{ i^\beta_{m+1}, \ldots i^\beta_n \right\}, i \text{ taking on all integer values from } 1 \text{ through } m.

In the example in the text we used the specific string } K_s N_N w V^-_i O^-_i. \text{ For the same string we show the results of using the more general formulation of type I C-equivalences.}

\[K_N w^+_{s_i} O^-_i \quad C \quad O'_i \quad \text{see text}
\]

\[" \quad C \quad V^+_{j_{ij}} \quad "
\]

\[" \quad C \quad w^+_{j_{ij}} \quad "
\]

\[" \quad C \quad N_{s_i} w^+_{j_{ij}} \quad "
\]

\[" \quad C \quad N_{s_i} w^+_{j_{ij}} \quad \text{whose painting the critics will consider a masterpiece and sculpture the museum will buy.}
\]

\[" \quad C \quad K_N w^+_{j_{in}} \quad \text{see text}
\]

\[\text{(this footnote is continued on page 31)}\]
whose painting the critics will consider a masterpiece and (whose painting the critics will consider) a discovery

" C (KN_s w) V_i^0_j whose painting the critics will consider a masterpiece and (whose painting the critics will) acclaim

" C (KN_s w) V_i^0_j whose painting the critics will consider a masterpiece and (whose painting the critics will) acclaim

" C (KN_s w) V_i^0_j whose painting the critics will consider a masterpiece and (whose painting) the public will reject

" C (KN_s w) V_i^0_j whose painting the critics will consider a masterpiece and whose courage the public will admire

Suppose C occurs in the sentence formula immediately following V_i; we have:

[In the example we use the string K_s N_s w V_i^0_i ]

KN_s w V_i C (KN_s w) V_i {O_i} whom the party will nominate and (whom the party will) elect president

" C (KN_s w) V_i {O_i} " " " " " " (whom the party) may elect president

" C (KN_s w) V_i {O_i} " " " " " " but (whom) people won't elect president

" C (KN_s w) V_i {O_i} " " " " " " but whom people won't elect president

Similarly, if C occurs in the sentence formula immediately following w, we have

KN_s w C (KN_s w) {V_i^0_i} whom she can but (whom she) may not invite

" C (KN_s w) {" } " " " " (whom) he can't help

" C (KN_s w) {" } " " " " whom they won't recommend
The general pattern of type I C-equivalences is clear.¹ For C occurring in the sentence formula somewhere among the elements of string β, what occurs to the right of C in the sentence formula is a structural parallel (repetition of the class marks) of some one of a set of segments derivable from the portion of β which occurs to the left of C. In particular the set contains every different segment of β on the left which reaches up to C. If some member(s) of β have not yet occurred in the sentence formula, i.e. are still required, these elements are expected to follow the occurrence of the C-equivalent elements in the sentence formula. The portion of β on the left which is not structurally paralleled on the right may be said to be present on the right in zeroed form.

Should C occur inside an object string, if the Object String is not of the β-type, the equivalences are those listed for the verb phrase.² If the object string is of the β-type, the equivalences which apply are those now being stated (type I) for strings, but in addition the equivalences may be applied to the string of which the object string is a member, e.g. We knew that he, and assumed that she, had read the article. This statement, is equivalent to the "scope" restrictions on object strings and replacement strings stated in 3.5 below. There is sometimes a question as to whether an object string equivalence can be expanded to make an equivalence of two strings on the level of the string containing the object string. E.g. He based

¹See also footnote on p. 30.

²See section 3.3 above, formula (4) and the discussion following (4), pp. 22, 3.
his conclusions on their data and my theories. Is this: He based his conclusions on their data and (he based his conclusions on) my theories?

When C occurs in the sentence formula at the end of a string β (i.e. immediately following $O_1$), a second type of C-equivalence may be found.

**Type II C-equivalence**

IIa. $N_s w_{i_1} - O_1 C N_s (w_{i_1} \pm O_1)$ e.g. His first book succeeded and the second one (succeeded) too.

IIb. " $C N_s (v_{i_1} \pm O_1)$ e.g. " " " " but the second one didn't (succeed).

IIc. " $C N_s (w_{i_1} \pm O_1)$ e.g. He wrote novels and she (wrote) poems.

Note that in type II equivalences the initial portion of β is paralleled on the right and a terminal or middle portion is zeroed, whereas in type I equivalences, a terminal portion is paralleled (sometimes in part shared) on the right and an initial portion is zeroed. In strings like $K w^+$ which have no $N_s$ the initial portion is the $w$ and only IIb is possible. (e.g. Those who could have helped but didn't).

It is interesting that one formally possible equivalence does not occur, namely

$N_s w_{i_1}^+ O_1 C N_s w_{j_1}^- (O_{i_1})$ e.g. He shattered the glass and she mended (the glass).

---

1Type II equivalences are stated for the general form of a string,

$\beta = N_s w_{i_1} O_1$

The string identifier $K$ may or may not occur in any of the equivalences.

2$N_s$ is dropped from the equivalence. See p. 30.
We also find that certain $V$ in different subclassifications $\gamma$, where the $\gamma$s have a common terminal portion, sometimes (but seemingly rarely) enter into $C$-equivalences. We give a few examples which range from comfortable to impossible.

\begin{itemize}
    \item $w^V_N \ C \ w^V_{PN} \ P' \ \{N\} \quad \text{e.g. They engaged and relied on assistants}$
    \item $w^V_{PN} \ P \ C \ w^V_N \ \{N\} \quad \text{e.g. They listened to and recorded conversations}$
    \item $w^V \text{ to } V^+ \ C \ w^V_N \text{ to } V^+ \ N' \ \{V^+\} \quad \text{e.g. He likes and has the desire to work}$
    \item $w^V_N \text{ to } V^+ \ N \ C \ w^V \text{ to } V' \ \{V^+\} \quad \text{e.g. Having the desire and meaning to work}$
    \item $w^V_{PN} \ C \ w^V_{NPN} \ N' \ \{PN\} \quad \text{e.g. They relied and based their conclusions on testimony from paid witnesses}$
    \item $w^V_{NPN} \ N \ C \ w^V_{PN} \ \{PN\} \quad \text{e.g. They referred decisions and deferred to their senior}$
    \item $V_A \ C \ w^V_{NA} \ N' \ \{A\} \quad \text{e.g. They seemed and considered others foolish}$
    \item $w^V_{NN} \ C \ w^V_{NN} \ {1} \ \{NN\} \quad \text{e.g. He gave and considered her a pearl}$
    \item $w^V_N \ C \ w^V_{N} \ {1} \ \{NN\} \quad \text{e.g. He saw and seemed a native}$
\end{itemize}

We sometimes find a $C$-equivalence involving an adjunct $PN$ and an object string which ends in $N$, e.g.

\begin{itemize}
    \item They bought tickets for and went to see Marcel Morceau $P \ C \ V \text{ to } V_N \ \{N\}$
    \item The boys who liked and shined the shoes of soldiers $V_N \ C \ V_N \ N \ P \ \{N\}$
\end{itemize}

Left adjuncts of $V$ which occur to the left of $V$ or $w$ in a $C$-equivalence may adjoin $V$ or both $V$ and $V'$:

\begin{itemize}
    \item $w^V \ C \ w^V' \quad \text{e.g. he will quickly return and report to us}$
    \item $\quad \text{e.g. they often watch or listen to the rehearsal}$
\end{itemize}

---

1There are two different verb-subclasses having the form $N$, and two having the form $NN$. 
Why? Possibly what is involved is the fact that a verb has not one possible object string but a set of possible object strings. In general, when a symbol (class) occurs on both sides of $C$, it is not the same word member which occurs on both sides, but different word members (see examples). So in the equivalence being discussed: $V_i$ occurs on the left and $V_j$ on the right, both are in the same verb class $V_γ$ which has $γ$ as object string, i.e. appears on the list of object strings for both $V_i$ and $V_j$. $O_i$ is an instance of $γ$. The string grammar allows a verb to occur with any $l$ of its object strings. Therefore, as soon as $V_j$ occurs in the sentence formula, as far as the grammar is concerned, it is free to choose any one of its objects. But the equivalence relies on $O_i$ being the chosen object of $V_j$. There is nothing in the string grammar to assure this will be the case, hence the equivalence is not usable.

A few examples should indicate how type II equivalences look in adjunct strings.

<table>
<thead>
<tr>
<th>Type of C-Equivalence</th>
<th>String</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>II a $K_{NN} wV_i^{-} O_i$</td>
<td>A teacher whose methods the children like and the mothers also</td>
<td></td>
</tr>
<tr>
<td>II b $K_{N} wV_i^{-} O_i$</td>
<td>The route which the guide recommended but you didn't.</td>
<td></td>
</tr>
<tr>
<td>II c $pK_{N} wV_i^{+} O_i$</td>
<td>A man with whom she discusses politics and he art</td>
<td></td>
</tr>
</tbody>
</table>

---

There are some reasons for considering be to be an incomplete verb, rather like w. In line with this we find the C-equivalence

$$N_s wV_i^{+} O_i \quad C \quad N_s wV_i^{+} (O_i)$$

for the verb be but no other verb. E.g. we have

He was a poet but she wasn't (a poet).

but not

He wrote poetry but she didn't write (poetry).
K N_i to V_i - O_i C 0_i whose painting the critics will consider a masterpiece and a discovery
" C V_j - O_j " " " " " " " and acclaim " C wV_j - O_j " " " " " " " and will acclaim " C N_s wV_j - O_j " " " " " " " and the people will reject " C KN_j wV_j - O_j " " " " " " " and whose courage the public will admire

The above C-equivalence can be shown to consist of two whole strings conjoined by C in which those elements on the left which do not appear on the right are actually there in zeroed form. The zeroed elements are not only the same structural entities but the same words as are on the left in the analogous position. We repeat the above C-equivalences showing the zeroed elements in parentheses.

E.g. for m = 3, \( \beta = K_{NN} V_i - O_i \), we would have

\[
\begin{align*}
i = 3 & \quad K_{NN} s C N_s \{ wV_i - O_i \} \text{ whose painting the critics but not the public admired} \\
i = 2 & \quad K_{NN} s C NN_s \{ " " \} " " " " \text{ and sculpture the public admired} \\
i = 1 & \quad K_{NN} s C K_{NN} s \{ " " \} " " " " \text{ and whose courage the public admired}
\end{align*}
\]

Note that the equivalence for i=2 is admitted by the general formulation but not by the formulation in the text.
\[(3) \quad N_s w_i \cap N_s w_j \cap C \quad N_s (w_i) \cap N_s (w_j) \quad \text{e.g. We hoped the green team would beat the red and you (hoped) the red (team would beat) the green.}\]

\[(4) \quad N_s w_v \cap N_k w_j \cap C \quad N_s (w_v) \cap N_k w_j \quad \text{e.g. We interviewed people who witnessed the events and you (interviewed) people who didn't (witness the events).}\]

In each of the above C-equivalences, on the left there are two strings, one including the other, and on the right a similar construction, with a type II C-equivalence holding between each pair of strings in corresponding positions.

<table>
<thead>
<tr>
<th>Double C-equivalence</th>
<th>Inclusion Relation</th>
<th>Including-string C-Equivalence</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Second string is object string of verb in first string</td>
<td>Hc</td>
<td>IIa</td>
</tr>
<tr>
<td>(2)</td>
<td>&quot;</td>
<td>&quot;</td>
<td>IIb That (sentence introducer of object string) must be zeroed</td>
</tr>
<tr>
<td>(3)</td>
<td>&quot;</td>
<td>&quot;</td>
<td>IIc selection of contrasting word pairs needed</td>
</tr>
<tr>
<td>(4)</td>
<td>Second string is adjunct of element in the first string</td>
<td>&quot;</td>
<td>IIb More comfortable than IIa or IIc in included string</td>
</tr>
</tbody>
</table>

Notice that (1)–(3) exhaust the possibilities for the object inclusion relation since IIa and IIb applied to the including string would result in losing the included string. Theoretically adjunct inclusion should permit all combinations of type II equivalences but actually few occur.
In addition to the equivalences discussed so far, there is one "limiting case" of zeroing. For a particular class of sentence adjuncts $\overline{D \overline{D}}$, $PN$, $PA$, to $V^-$, and strings beginning with $t_2$ or $t_3$ (see table____), we may have $I'$.

$N_wV_iO_i \quad C \quad (N_wV_iO_i) \overline{D}$ e.g. We left and (we left) fast

e.g. We bought them ice cream but (we bought them ice cream) to keep them quiet.

When $C$ occurs at the end of a string, we have a further (type III) $C$-equivalence. Let [$\beta$] stand for any member of a given class of strings, e.g. right adjuncts of $N$, sentence adjuncts. Then

III $[\beta] \quad C \quad [\beta]$ e.g. The delegates elected but not receiving an absolute majority ($\text{strings } S^-, G^-$)

Actually not all [$\beta$] are $C$-equivalent. We find more awkward: The delegates elected but who did not receive an absolute majority ($\text{strings } S^+, K_1V^+$) and almost impossible: The man whose car we borrowed and from Philadelphia

(Strings $\overline{K_1NWV^-}, PN$).

Double zeroing

Consider the following "double $C$-equivalences" (zeroed elements in parentheses):

1. $N_wV_i[N_wV_jO_j] \quad C \quad N_s(wV_i)[N_s(wV_jO_j)]$ e.g. I claim that the police were carrying arms and you (claim) that the demonstrators (were carrying arms).

2. $N_s(wV_i)[N_s(wV_jO_j)] \quad C \quad N_s(wV_i)[N_s(wV_jO_j)]$ e.g. I claim that the men carried a flag and you (claim) that they didn't (carry a flag).
3.5 Scope of C-Equivalences

If we consider \( \alpha \) a variable name for the structure to the left of C in the sentence formula which is paralleled by a structure \( (\alpha') \) to the right of C, then the range of the values of \( \alpha \) can be stated in terms of a string analysis of the sentence formula to the left of C. (This is convenient for a left to right analysis).

Let \( \beta_i \) designate a string which is represented (\( \geq \) has at least one member) to the left of C in the sentence formula, \( i \) increasing leftward from C, \( i=0, 1, 2... \). Further, let \( k \) stand for the relative depth of a string, i.e. if \( \beta_i \) is at depth k and string \( \beta_j \) is an adjunct of \( \beta_i \) or of a symbol in \( \beta_i \), then \( \beta_j \) is at depth \( k + i \).

Given a string structural analysis of a sentence formula to the left of C, the determination of \( \alpha \) in the C-equivalence \( \alpha \in C \alpha' \) is as follows:

1. If C falls inside \( \beta_o \) (= not at the end of \( \beta_o \)), then \( \alpha \) is in \( \beta_o \) and the C-equivalence which applies is type I.

2. If C falls at the end of \( \beta_o \), and \( \beta_o \) is an adjunct string, then \( \alpha \) lies in some \( \beta_i \) whose relative depth \( k_i \) does not exceed the relative depth \( k_j \) of a \( \beta_j \) represented between \( \beta_i \) and C; the C-equivalences which apply are types I, II, III.

3. If C falls at the end of \( \beta_o \), and \( \beta_o \) is an object string or a replacement string, we can determine where \( \alpha \) lies, using 1 and 2 above as follows:
   a) Apply 2, as if there is no \( i > o \). This covers the possibility \( \alpha \in \beta_o \).
   
   b) Replace \( \beta_o \) by one symbol (0 if \( \beta_o \) = object, N if \( \beta_o \) = replacement of N). C now falls inside or at the end of \( \beta_i \), the string which includes 0 or N. Substitute \( \beta_i \) for \( \beta_o \) in 1. and 2. above, and apply 1 and 2.
Example. We show a set of sentences which have the same initial portion up to C but differ in the portions following C because of different values of α. The common initial portion is shown analyzed as to its string structure, preceding the set of sentences. Relative depth is shown by writing a string of depth $K + 1$ below a string of depth $k$; strings represented to the left of C are numbered according to the convention stated at the beginning of this section.

Initial segment:

\[
N_{\beta_2} \quad P_{\beta_4} \quad N_{\beta_3} \quad V^+_{\beta_2}\ 
\]

A group of chemists performed an experiment in Washington which we repeated yesterday.

\[
K_{\beta_1} \quad N_{\beta_0} \quad V^-_{\beta_2} \quad D_{\beta_0}
\]
<table>
<thead>
<tr>
<th>String which contains $\alpha$</th>
<th>Type of C-equivalence</th>
<th>C-Equivalence $\alpha' C \alpha'$</th>
<th>Sentence illustrating the C-Equivalence of column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0 = D$</td>
<td>I</td>
<td>$D C D'$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and today</td>
</tr>
<tr>
<td>$\beta_1 = K_N s^w V_i^{-1} O_i$</td>
<td>I</td>
<td>$K_N s^w V_i^{-1} O_i C$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and are now analyzing</td>
</tr>
<tr>
<td>I</td>
<td>$K_N s^w V_i^{-1} O_i C$</td>
<td>$N w^V O_i'$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and other laboratories have also repeated</td>
</tr>
<tr>
<td>I</td>
<td>$K_N s^w V_i^{-1} O_i C$</td>
<td>$K_N s^w V_i^{-1} O_i'$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and which others may find interesting</td>
</tr>
<tr>
<td>I'</td>
<td>$K_N s^w V_i^{-1} O_i C^D$</td>
<td>$N w^V O_i'$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and with result</td>
</tr>
<tr>
<td>IIa</td>
<td>$K_N s^w V_i^{-1} O_i C$</td>
<td>$N'$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and others also</td>
</tr>
<tr>
<td>IIb</td>
<td>$K_N s^w V_i^{-1} O_i C$</td>
<td>$N w'$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and others will also</td>
</tr>
<tr>
<td>IIc</td>
<td>$K_N s^w V_i^{-1} O_i C$</td>
<td>$N_s O_i$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and others will also</td>
</tr>
<tr>
<td>III</td>
<td>[r. adj. of N] C</td>
<td>[r. adj. of N]'</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and whose results may interest others</td>
</tr>
</tbody>
</table>

The table above lists various sentences that illustrate the C-Equivalence relations.
<table>
<thead>
<tr>
<th>String which contains $\alpha$</th>
<th>Type of C-Equivalence</th>
<th>C-Equivalence</th>
<th>Sentence illustrating the C-Equivalence of column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_2$ $B_s w V_{i_1} O_{i_1}$</td>
<td>I</td>
<td>$N_s w V_{i_1} O_{i_1} C$ $O_{i_1}$</td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and certain calculations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$N_s w V_{i_1} O_{i_1} C$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{i_1} O_{i_1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>same as following</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>line in this case</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>$N_s w V_{i_1} O_{i_1} C$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$w V_{i_1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$O_{i_1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>$N_s w V_{i_1} O_{i_1} C$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$w V_{i_1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$O_{i_1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I'</td>
<td>$N_s w V_{i_1} O_{i_1} C$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\overline{D}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IIa</td>
<td>$N_s w V_{i_1} O_{i_1} C$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$N_s$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IIb</td>
<td>$N_s w V_{i_1} O_{i_1} C$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$N_s$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IIc</td>
<td>$N_s w V_{i_1} O_{i_1} C$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$N_s O_{i_1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and another group also</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and another group did also</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A group of chemists in Washington performed an experiment which we repeated yesterday and a group of mathematicians the calculations</td>
<td></td>
</tr>
</tbody>
</table>
For $\beta = 2$, the equivalences with zeroings are quite awkward. One might say that as the two parts of a C-equivalence become separated, the occurrence of the C-equivalence with zeroings becomes less likely.

Notice that for $\beta_3$ and $\beta_4$ no C-equivalence is possible because the depth of $\beta_3$ and $\beta_4$ are each greater than the depth of a string to their right, $\beta_2$.

E.g. we could not have

$\beta_3$ A group of chemists in Washington performed an experiment which we repeated yesterday and with whom we have corresponded.

$\beta_4$ A group of chemists in Washington performed an experiment which we repeated yesterday and of biologists.

3.6 Scope markers

Sometimes the scope of a C-equivalence is marked in the sentence formula by the occurrence of a particular symbol; then the scope rules of 3.5 apply only to the stretch of the sentence formula between C and the scope marker.

The idea of scope markers is presented here as a hypothesis to explain the function of certain words which sometimes occur in disjoint association with particular conjunctions. These words also occur in sentence where they are not in special relation to conjunctions, but it seems that the two functions can be separated: either the word occurs as part of a nounphrase, or it occurs in a wide distribution where it has no grammatical function other than marking the scope of a C-equivalence.

In this section three pairs of conjunction-and-scope-marker are considered

<table>
<thead>
<tr>
<th>Scope Marker</th>
<th>Associated with</th>
<th>Example of Scope-marked C-equivalences</th>
</tr>
</thead>
<tbody>
<tr>
<td>both</td>
<td>and</td>
<td>They both plastered and painted the walls</td>
</tr>
<tr>
<td>either</td>
<td>or</td>
<td>Either he or I will go</td>
</tr>
<tr>
<td>neither</td>
<td>nor</td>
<td>Neither God nor country saved him</td>
</tr>
</tbody>
</table>

The conjunction but has no scope-marker. It may turn out that the pairs er...than\(^1\) and as...as (comparatives can be treated as conjunction plus scope-marker. On

\(^1\)The comparative morpheme -er occurs in A-er (prettier, finer), more, less, rather, worse, D-er, and possibly other forms.
these we first need to know in some detail how the C-equivalences and morphophonemic zeroing operate.

The conjunctions and, or can each occur without a preceding scope marker, e.g. both he and I, he and I; however, if both or either or neither occurs in a sentence, it must be followed, at some distance, by its associated conjunction. The case with er...than is the opposite: the conjunction than does not occur except preceded by -er, the -er morpheme, however, may occur without a following than, e.g. This is more likely the case.

When a scope marker is followed by two occurrences of its associated C in a sentence formula, e.g. Either he or I will buy or borrow a pen or pencil, there is a question as to whether the scope marker functions in association with one C or with more than one C. A starting guess is that it operates independently with each C.

As we noted, the words either, neither, and both have more than one classification, e.g. in Either type will do, either is an article, T, and in Either he will go or I will, it is a scope marker (henceforth written Σ). A decision can sometimes be made because of the environment. The following is a preliminary list of environments and classifications.\(^1\)

<table>
<thead>
<tr>
<th>Word</th>
<th>occurs</th>
<th>classification</th>
<th>example</th>
</tr>
</thead>
<tbody>
<tr>
<td>either, neither</td>
<td>Before T</td>
<td>Σ</td>
<td>Either the matter will be settled soon or not at all</td>
</tr>
<tr>
<td></td>
<td>Before R (pronoun)</td>
<td>Σ</td>
<td>Either he or I will go</td>
</tr>
<tr>
<td></td>
<td>Before N(_p1) (plural noun)</td>
<td>Σ_{-2}^T</td>
<td>Either children are disciplined or spoiled</td>
</tr>
<tr>
<td></td>
<td>Before N(_l) (count noun)</td>
<td>Σ_{-2}^T</td>
<td>Either type will do</td>
</tr>
<tr>
<td></td>
<td>Before N(_{sg'#1}) (singular, not count noun)</td>
<td>Σ_{-2}^T</td>
<td>Either language can be used. Either language is described formally or culturally</td>
</tr>
<tr>
<td>both</td>
<td>Before T</td>
<td>Q(_T)</td>
<td>Both the men are literate</td>
</tr>
<tr>
<td></td>
<td>Before of</td>
<td>Q(_T)</td>
<td>Both of the men are literate</td>
</tr>
<tr>
<td></td>
<td>Before R</td>
<td>Σ(_T)</td>
<td>Both we and they attended</td>
</tr>
<tr>
<td></td>
<td>Before N(_p1)</td>
<td>Q(_T)/Σ</td>
<td>Both men came</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Both men and women came</td>
</tr>
</tbody>
</table>

\(^1\)Where N appears is an environment, it is to be understood that \(\overline{AN} = N\) and that N is not a left portion of a compound noun.

\(^2\)Either and neither also occur as a noun (either will do). In TDAP 27 \(T\(_4\)\) (either, neither) is a subclass of \(T\) which also is listed among the replacement strings of N. Similarly Q\(_T\) may occur as a noun. See p. 21, p. 26.
4. Left Adjuncts and the Analysis of the Nounphrase

For present purposes the left adjuncts of N can be divided into 3 groups:

a) Article-quantifier classes T, B, Q_T, D_T, Q.
b) Adjectival elements: A, S, G, Z, N's
c) The left portion of compound nouns: N, NA, NS, NG or any combination of these

Each of these presents certain special features, or problems for string computation. For a) it is a question just now of obtaining a more refined classification of the elements and establishing their relative order of occurrence in the nounphrase. In b) there are sometimes ambiguities of an associational kind, e.g. in hazy blue sky, is the sky hazy or is the blue hazy? The problem here is to state for which elements in which positions more than 1 grouping of the elements is possible and to provide a systematic procedure for obtaining all the groupings (and perhaps to select the more probable among the groupings).

In c) there are two questions, one which concerns the analysis of the compound noun itself (more a transformational than a string analysis problem) and another which involves ambiguous sequences, e.g. does a particular sequence of Ns constitute one nounphrase or more than one nounphrase, for example flint tools is a compound noun in the flint tools were made into spear-like shapes, but is two nounphrases in the flint tools were made of was of local origin. Of these problems, those concerning b) and c) are discussed below.

4.1 Adjectival elements

Sequences of A, S, G elements in a nounphrase are in general independent of each other and adjoin an element farther to the right, i.e. A, S, G, elements are not nested among themselves. 1 Thus there is only one grouping for the

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1A sequence of pure As in a noun phrase sequence presents no problem in grouping; each A is an independent adjunct either of the first N's to the right or of the "head" (rightmost) noun of the noun phrase. However, when the verb-derived adjectival elements S, G are introduced into the sequence, there may be some question as to the grouping. Most often these, too, are independent, e.g. The measured optical density

\[
S \quad A \quad N
\]

additional reverberating circuits

\[
A \quad G \quad N
\]

But we find

slow moving plane the assumed correct results long-lasting facilitation

\[
A \quad G \quad N \quad S \quad A \quad N
\]

((  )  ) ((  )  )

((  )  )

where the elements are not grouped independently.

(footnote continued on page 45)
A, S, G in each of the following examples:

\[
\text{cheerful young man} \\
\text{A A N} \\
( ) ( )
\]

The outlying newly constructed residential districts.

\[
\text{G D S A N} \\
( ) ( ) ( ) ( )
\]

However, certain adjectival elements may themselves have left adjectival adjuncts, e.g. Z (color words), so that if a sequence of A, S, G elements is followed by Z N, several different groupings are possible: the A S G sequence (or certain parts of it) may adjoin Z or may adjoin N. Making a separate class Z is in part based on this distributional fact.²

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² The distributional characteristics of color word Z which distinguish them from pure nouns like hat, mass and from pure adjectives like young, cheerful are:

They can occur as an adjective, e.g. blue dress
They can occur as a noun, e.g. Blue is my favorite color
They can draw left adjuncts from among A, S, G, Z (in a noun phrase) e.g. pale blue dress
e.g. frosted blue color
startling bluelake
green blue sky

They can occur as the left portion of a compound noun, e.g. blue period
[The latter is distinguished from the adjective occurrence by stress patterns. For instance, contrast the painter's blue mood with Picasso's blue period].

On the same grounds another class is suggested, call it Y, of words like stone, copper (roughly, words describing materials). They occur, corresponding to the above,

As adjective e.g. stone wall
As noun e.g. Stone is stronger than brick
With left adjuncts in the Nounphrase e.g. hard stone wall
chipped stone tools
flaking stone walls
tungsten steel plate

As the left portion of a compound noun, e.g. stone age
[To distinguish the latter from the adjective occurrences, contrast stone wall with stone age, copper tubing with copper compound].
The following example shows the possible groupings of A, S, G elements preceding Z N and how the groupings increase as a function of the number of A, S, G elements. If there are n A, S, G elements preceding Z N, there are n+1 groupings of the entire sequence.

The hazy blue sky
{( ) ( )
     ( )
}

The pale hazy blue sky
( ) ( ) ( )
( ) ( ) ( )
( ) ( ) ( )

The fading pale hazy blue sky
( ) ( ) ( ) ( )
( ) ( ) ( ) ( )
( ) ( ) ( ) ( )
( ) ( ) ( )

The element N's may also have left adjuncts, but unlike Z, any A, S, G which occurs to the left of 1 or more N's, adjoins the left-most N's, and may not equally well adjoin the head N of the nounphrase. Hence for n A, S, G elements preceding N's, N, there is one grouping

e.g. Underdeveloped country's youth
{( )
}

One might accept a second grouping of the above example

e.g. underdeveloped country's youth
( ) ( )
in which underdeveloped is associated with youth, but I believe such an intended association would occur as country's undeveloped youth.

One notes that the groupings of A S G elements before Z N is the complement of the groupings of A S G elements before N's N, with regard to the set of all possible groupings which do not violate non-intercalation. If this has significance, perhaps N's and Z represent two different ways of allowing adjectival elements to adjoin other adjectival elements.
c) Compound noun

We now consider sequences of noun phrase symbols which might contain compound nouns, i.e. which have on the right NN or NAN or NGN or NSN or combinations of any of these. There is a question as to whether such a sequence constitutes one or more noun phrases. We discuss below several restrictions which can be made in making the decision.

1. Count noun restriction: the sequence cannot be broken in such a way as to leave a count noun in the final (rightmost) noun position with no T or B preceding it in the noun phrase.

Frequent cases:

a) The final (rightmost) noun of the sequence is a count noun. Therefore, the whole sequence between article (T or B) and final noun is one noun phrase. Example of sequences decided by (a) are:

A 10-40 percent w/r sucrose density gradient was prepared according to the method of B. & L.

What he thought as a syndicalist in the USA he did as a trade union organizer in Ireland.

Connolly never knew the vanguard party.

The paintings and engravings at Lascaux are attributed to the peak period of Perogordian art.

Some blackist marks which resembled the deposit of a grease lamp were found.

The sedimentation coefficient of mosaic virus was measured in a Spinco model E analytical ultra centrifuge.

b) There is no initial T or B; therefore the sequence cannot be broken in a way that leaves the left portion terminating in a count noun.

Examples of (b) are:

The date of Lascaux within the framework of Franco-Cantabrian wall art can be estimated by a study of the styles and superpositions of the paintings in relation to the known stages of cave art. (count nouns: wall, cave)

These experiments consisted of infectively and particle assays of fractions obtained by density gradient centrifugation. (count nouns: particle, gradient)
2. Plural: A compound noun does not contain a plural noun in non-final position. Example:

In the caves remains belonging to Homo Sapiens cover those of the Last Neanderthals.

3. Pronouns: A compound noun does not contain pronouns. Example:

They worked flint blades compared with stone worked flint blades

4. Comma: A compound noun does not contain a comma.

Suppose a sequence can be divided into two (or more) noun phrases on internal grounds. Are further restrictions available by considering the immediate context? We first take up in what cases we find two adjacent noun phrases in a sentence.

Two adjacent noun phrases can occur in the following cases:

a. In a single string

After a verb which has the string NN as one of its possible objects

verbs like give e.g. They gave the boy books for his birthday
" " elect, make we elected a woman president
" " make the children toys
" " consider we consider him a fool

In the sentence adjunct NN
e.g. The first book a success, they contracted for a second.

b. At the border of two strings

b1. The second noun phrase is the beginning of a right adjunct of N or of a sentence adjunct.

The right adjuncts of N which begin with N are:

N (apposition) e.g. the local lesion host chenopodium
hybridum the evil man can inflict

NV–

NV+ (only after N_b)

NPK strings ... samples of which we tested

The sentence adjuncts which begin with N are:

N_b strings (6 in number. e.g. His mission accomplished, he ...
See Sect 1. part d.)
N V^14_k (V^14_k = verbs like know) These results we relaize, are ...
N_7 (N_7 = time words) People today
Since right adjuncts of N are always permitted after N, and sentence adjuncts are permitted after N in most positions, the occurrence of contiguous N's in the sentence formula would seem to give rise to many different analyses. Actually most of the above string rarely occur without a comma to set them off from the preceding noun phrase, and some of them occur infrequently even with a comma. For the moment we are only considering sequences of noun phrase elements which could constitute either a single noun phrase or several noun phrases, not the entire problem of consecutive N's. E.g. we consider the evil man can inflict but not the evil a man can inflict, although in the latter, while there is no ambiguity as to the number of noun phrases, the problem of assigning string status to the two noun phrases still exists. The remarks to follow concerning commas and other restrictions apply to sequences of noun phrases in general, but they are stronger for the ambiguous case because often an unambiguous grammatical separation of two noun phrases functions to establish a string boundary whereas when there is no grammatical separation, a comma is practically mandatory.

Certain restrictions on right and sentence adjuncts which begin with N are:

- **N O B strings** absolutely rare
  - almost never occur without a comma separating its initial or final element from adjacent sentence elements.

- **N apposition** rare without a comma
  - When the N apposition is a name it sometimes occurs without comma,
    - e.g. The painter Picasso
  - The local lesion host Chenopodium hybridum

- **N P K strings** rarely without a comma
  - e.g. Bacteriophage $\gamma \times 174$ top and bottom components
    - the particle densities of which in rubidium chloride are 1.32 and 1.40
    - respectively, were added to the virus solution.
    - The particle, the characteristics of which we have described, is indeed the infectious virus.

- **N V** never with a comma preceding N
  - e.g. not: The evil, man can inflict, is ...
  - The V" of N V" implies further restrictions. For example, the evil man exists could not be interpreted to contain an N V" string because V" implies the omission of an N from the verb object and exists is intransitive. If the verb following an N N (ambiguous sequence is passive, the NN is almost surely not a noun followed by N V" because then the verb object would have to be such as to allow two N omissions.
Examples of decisions against $N V^-$:

Diffusion experiments were carried out.

Apparent diffusion co-efficients were calculated

... in which the nucleoprotein content is determined by ...

Some flint tools were found lying just under the surface of the clay.

b2. The second noun phrase is the beginning of a replacement string of $N$ ($N G^+$ or $N G$).

b3. All the other border cases. Actually, since b1 and b2 exhaust the list of strings which begin with $N$ (except $N V^+$ center string) the only other broader possibility is that the first noun phrase be the end of a string, and the second noun phrase be "the next required member" of the including string. Although a comma is often present, especially if the adjunct ending in $N$ is long, there seems to be no rule to apply. But since cases b1. does have restrictions, if one can establish that the noun phrase sequence in question is not at the end of a string, then the problem of deciding whether an ambiguous sequence constitutes one noun phrase or more than one, is considerably simpler. For example, a noun phrase, sequence at the beginning of a sentence as such a case. It can only contain a string border when the first noun phrase is itself a complete string, such as $N_\gamma$ (time words)

e.g. Today science is heavily administered,

or certain "expressions"

e.g. no wonder observers have commented that ...

The most frequent uncertain construction where the first $N$ is at the end of a string and the second $N$ is the next member of the including string seems to be $P N N$: in some cases $P N N \rightarrow P N P N P$

e.g. The citizen Army was in part members of the Irish Transport Workers Union.

In order to minimize the stress during reversal subjects slept all night on the last control period.

A comprehension of the evil man can inflict is necessary

and in other cases $P N N \rightarrow P N P$

e.g. From the sedimentation and diffusion coefficients at a virus concentration of 0.42 per cent the molecular weight was calculated.

We conclude on the basis of velocity and equilibrium sedimentation experiments that the particle, the characteristics of which we have described, is indeed the infectious virus.