XV. LINGUISTICS*

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A. ONE-WAY GRAMMARS

In Matthews,[1] I defined one-way grammar, discontinuous grammar, and one-way discontinuous grammar, and stated that I had succeeded in proving that one-way grammars and one-way discontinuous grammars are equivalent to context-free grammar and that discontinuous grammars are equivalent to context-sensitive grammars as defined by Chomsky.[2] These proofs appear in Matthews.[3] In this report I show that the restrictions on the form of the rules are not essential; any unrestricted rewriting system generates a context-free language if its derivations are confined to one-way derivations as defined in Matthews.[1,3]

DEFINITION 1: A grammar is a finite set of rules, each of which has either the form $X \rightarrow Y$ or the form $A \rightarrow a$, where X and Y are strings of nonterminal symbols which are possibly null, A is a single nonterminal symbol, a is a single terminal symbol, and $X \neq Y$.

DEFINITION 2: A left derivation is a sequence of strings $(\phi_1, \ldots, \phi_n)$ such that $\phi_1 = S$, and for each i $(1 \leq i < n)$ there are strings x, X, Y, ω such that $X \rightarrow \omega$ is a rule of the grammar, $\phi_i = xXY$, and $\phi_{i+1} = x\omega Y$.

DEFINITION 3: The left language of a grammar is that set of terminal strings generated by the grammar, all of which have left derivations.

I shall now describe a machine, called a modified pushdown storage automaton (MPDS), which has the capacity to produce all and only the left derivations of a grammar. This machine has a control unit and two tapes T_I and T_S. The control unit can read the contents of T_S, and on the basis of these contents either erase the leftmost symbol of T_S and write a terminal symbol on the right end of T_I, or replace some leftmost string of T_S by another string, and one of these strings may be null. In particular, if at some step in the derivation of a sentence T_I contains the string x and T_S contains the string AZ and there is a rule in the grammar $A \rightarrow a$, then the machine will write a on the right end of T_I and erase the A from T_S; T_I will then contain xa, and T_S will contain Z. If at some step in the derivation T_S contains the string XZ, and if there is a rule in the

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grammar $X \rightarrow Y$, then the machine may replace the string X by Y, and T_S will then contain YZ.

The control unit of the MPDS has two states, the initial state S_0 and the working state S_1. The MPDS starts operating in the initial state with both tapes blank and goes to the working state writing the string $S\sigma$.

$$(e, S_0, e) \rightarrow (S_1, S\sigma) \tag{1}$$

For each grammar rule of the type $A \rightarrow a$, the MPDS will have an instruction that writes a on the right end of T_I and erases A from the left end of T_S.

$$(a, S_1, A) \rightarrow (S_1, \sigma) \tag{2}$$

For each grammar rule of the type $X \rightarrow Y$, the MPDS will have an instruction that replaces the string X by the string Y only if this string is a leftmost string on T_S.

$$(e, S_1, X) \rightarrow (S_1, Y) \tag{3}$$

And, finally, when the MPDS is scanning the σ on T_S which was placed there by instruction (1), it then will erase the σ, transfer to the initial state, and stop.

$$(e, S_1, \sigma) \rightarrow (S_0, \sigma) \tag{4}$$

It is clear that when this machine stops with T_S blank, the contents of T_I will be a sentence of the left language of the grammar, and that if some string x is a sentence of this left language, then there is a sequence of machine operations which will end with T_S blank and x on T_I. (Note that this machine can stop also when T_S is not blank. This will happen when there is no initial string of T_S that appears to the left of the arrow in a rule of the grammar. In such a situation we shall say that the machine is blocked and that the contents of T_I at that point are not a sentence of the language.)

THEOREM: For each MPDS there is an equivalent pushdown storage automaton (PDS).

PROOF: The proof is by a construction: The initial instruction of the PDS is

$$(e, S_0, \sigma) \rightarrow (S_1, S). \tag{5}$$

For each instruction of type (2) and of type (4) in the MPDS, there is an identical instruction in the PDS. And for each instruction in the MPDS of type (3), there is a finite set of instructions in the PDS. Suppose that MPDS has the instruction

$$(e, S_1, A_1 \ldots A_n) \rightarrow (S_1, B_1 \ldots B_m); \tag{6}$$

the PDS will have the set of instructions

$$(e, S_1, A_1) \rightarrow (S_{A_1}, \sigma) \tag{7}$$

$$(e, S_{A_1}, A_2) \rightarrow (S_{A_1 A_2}, \sigma) \tag{8}$$

$$(e, S_{A_1A_2}, A_3) \rightarrow \tag{9}$$

$$\vdots$$

$$\rightarrow (S_{A_1 \cdots A_n}, \sigma) \tag{10}$$

$$(e, S_{A_1 \cdots A_n}, e) \rightarrow (S_1, B_1 \cdots B_m). \tag{11}$$

Of course, if n = 0, then the only instruction in this set is

$$(e, S_1, e) \rightarrow (S_1, B_1 \cdots B_m), \tag{12}$$

and if m = 0, then the last instruction in the set is

$$(e, S_{A_1 \cdots A_n}, e) \rightarrow (S_1, e). \tag{13}$$

Q.E.D.

Chomsky[4] has shown that PDS's are equivalent to context-free grammars; therefore, the left languages of grammars are context-free languages.

Of course, we can define a right derivation and a right language of a grammar in a manner similar to the way in which we defined left derivation and left language of a grammar. And in a way similar to that of Matthews,[3] we can interpret instructions (1)-(4) so that they generate the right language of a grammar. Thus, this proof holds for both of the one-way languages of a grammar, i.e., the left language and the right language.

This theorem gives us another way of characterizing context-free languages. Whereas Chomsky[2] has characterized them in terms of the form of the rules of the grammars that generate them, we here characterize them in terms of the form of the derivations of their sentences. A context-free language is the set of sentences generated by a finite set of unrestricted rewriting rules, such that at each step in the derivation of a sentence only the substrings of a set which begin with the leftmost (rightmost) nonterminal symbol are candidates for being rewritten by a grammar rule.

G. H. Matthews

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2. N. Chomsky, On certain formal properties of grammars, Information and Control 2, 137-167 (1959).

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B. REGULAR LANGUAGES AND PUSHDOWN STORAGE AUTOMATA

In Section XV-A I defined a machine that I call a modified pushdown storage automaton (MPDS), and I showed that for each MPDS there is an equivalent pushdown storage automaton (PDS). The definition of MPDS shows that the converse is also true. The instructions of an MPDS are of the following types:

$$(e, S_0, e) \rightarrow (S_1, S\sigma) \tag{1}$$

This is the initial instruction, which states that if the MPDS is in the initial state (S_0), then it writes the string $S\sigma$ on the storage tape and switches to the working state (S_1).

$$(a, S_1, X) \rightarrow (S_1, Y) \tag{2}$$

When the MPDS is in the working state and reading a on the input tape, it replaces the string X at the end of the storage tape by the string Y, where a, X or Y may be the identity element.

$$(e, S_1, \sigma) \rightarrow (S_0, e) \tag{3}$$

This is the final instruction. When reading σ on the storage tape, the MPDS erases it and switches to the initial state.

We can make a further generalization on the form of MPDS instructions. We can regard the X and Y in the instructions of type (2) not as single strings but as variables over the sentences of the regular languages L_X and L_Y, respectively. Thus, instruction (2) is a schema for an infinite set of instructions: all of those that replace a sentence of L_X by a sentence of L_Y. This interpretation of instruction (2) does not actually increase the power of MPDS's; each such instruction can be replaced by a finite set of PDS instructions. Where L_X – with the initial state S_{X_0} – is generated by the instructions

$$(S_{X_0}, A) \rightarrow (S_{X_i}) \tag{4}$$

$$(S_{X_j}, B) \rightarrow (S_{X_k}) \tag{5}$$

$$(S_{X_m}, C) \rightarrow (S_{X_0}), \tag{6}$$

the equivalent PDS would have the instructions

$$(e, S_1, A) \rightarrow (S_{X_i}, \sigma) \tag{7}$$

$$(e, S_{X_j}, B) \rightarrow (S_{X_k}, \sigma) \tag{8}$$

$$(e, S_{X_m}, C) \rightarrow (S_{Y_0}, \sigma), \tag{9}$$

respectively; and where L_Y – with its initial state S_{Y_0} – is generated by the instructions

$$(S_{Y_0}, D) \rightarrow (S_{Y_i}) \tag{10}$$

$$(S_{Y_j}, E) \rightarrow (S_{Y_k}) \tag{11}$$

$$(S_{Y_m}, F) \rightarrow (S_{Y_0}), \tag{12}$$

the equivalent PDS would have the instructions

$$(e, S_{Y_i}, e) \rightarrow (S_1, D) \tag{13}$$

$$(e, S_{Y_k}, e) \rightarrow (S_{Y_j}, E) \tag{14}$$

$$(e, S_{Y_0}, e) \rightarrow (S_{Y_m}, F), \tag{15}$$

respectively.

In Matthews,[1] I gave a simple algorithm for writing the instructions of a PDS that would accept the language generated by any given context-free grammar. The corresponding MPDS instructions are instructions (1) and (3), and for each grammar rule of the form $A \rightarrow X$, the MPDS has the instruction

$$(e, S_1, A) \rightarrow (S_1, X), \tag{16}$$

for each rule of the form $A \rightarrow a$, the MPDS has the instruction

$$(a, S_1, A) \rightarrow (S_1, e). \tag{17}$$

But we have seen that instruction (16) can represent an infinite set of instructions: Thus, the corresponding context-free grammar would contain an infinite set of rules, viz., all of the rules that expand the symbol A into a sentence of the regular language L_X. The resulting grammar, of course, still generates a context-free language, for the reinterpretation added no power to the MPDS.

G. H. Matthews

References

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C. PRELIMINARY REMARKS ON THE MORPHOPHONEMIC COMPONENT OF POLISH

1. Introduction

In this report we make a few preliminary remarks on the morphophonemic component of Polish.[1] We suggest that sharping of consonants and nasalization of vowels in Polish is always predictable (and hence nonphonemic). Moreover, the occurrence of the palatals č ž š and of the glides j w is shown to be predictable. Furthermore, we want to indicate that at least some of the rather complex consonant and vowel alternations that occur in Polish inflection may be accounted for by a simple set of rules, all of which are of general application. In particular, we shall be concerned with the following types of alternation (the numbers below correspond to the numbers of the derivations that we give in sections 3 and 5):

1, 2: Nom. Sg. mięso : Gen. Pl. mięs 'meat'

3-5: Nom. Sg. ręka : Loc. Sg. ręce : Gen. Pl. rąk 'hand'

6, 7: Nom. Sg. gęba : Loc. Sg. gębie 'mouth'

8, 9: Nom. Sg. świat : Loc. Sg. świecie 'world'

10, 11: Nom. Sg. kara : Loc. Sg. karze 'punishment'

12, 13: Nom. Sg. pies : Gen. Sg. psa 'dog'

14, 15: Nom. Sg. sen : Loc. Sg. śnie 'sleep, dream'

16, 17: Nom. Sg. Bóg : Voc. Sg. Boże 'God'

18, 19: Nom. Sg. kto : Emphat. Nom. Sg. któż 'who'

20, 21: Nom. Sg. anioł : Loc. Sg. aniele 'angel'

22, 23: Nom. Sg. lew : Gen. Sg. lwa 'lion'

24, 25: Nom. Sg. las : Loc. Sg. lesie 'forest'

26, 27: Nom. Sg. mucha : Dat. Sg. musze 'fly'

28-30: Nom. Sg. chłopiec : Gen. Sg. chłopca : Voc. Sg. chłopcze 'boy'

31: Nom. Masc. Sg. prosty : Nom. Masc. Pers. Pl. prości 'simple'

32: Nom. Masc. Sg. głuchy : Nom. Masc. Pers. Pl. głusi 'deaf'

33-35: 1 Sg. piekę : 3 Sg. piecze : 3 Pl. pieką 'bake'

36-39: 1 Sg. niosę : 3 Sg. niesie : 3 Pl. niosą : Past niósł 'carry'

40-42: 1 Sg. idę : 3 Sg. idzie : 3 Pl. idą 'go'

43-45: 1 Sg. noszę : 2 Pl. nosicie : 3 Pl. noszą 'carry'

46, 47: Inf. obrazować : 2 Pl. obrazujecie 'illustrate, exemplify'

48, 49: Inf. robić : Imperative rób 'do'

50, 51: 1 Sg. widzę : 2 Pl. widzicie 'see'

52, 53: 1 Sg. jeżdżę : 2 Pl. jeździcie 'ride'

54, 55: 1 Sg. strzygę : 2 Pl. strzyżecie 'cut (hair)'

56, 57: Inf. pić : 2 Pl. pijecie 'drink'

58, 59: Inf. myć : 2 Pl. myjecie 'wash'

In this report we shall also give a provisional account of the following types of liquid diphthongs in Polish:

60: członek (cf. PS keln+os) 'member'

61: głód (cf. PS gold+os) 'hunger'

62: brzeg (cf. PS berg+os) 'shore'

63, 64: Inf. mleć : 2 Pl. mielecie (cf. PS mel+tī : mel+e+te) 'grind'

65: kiełbasa (cf. PS kulbōs+ō) 'sausage'

In examples 66 and 67 we show how the Masc. Gen. Sg. dobrego 'kind' and the 2 Pl. kochacie 'you love' may be accounted for within the limits of our proposed morphophonemic component.

We require for Polish the conventional inventory of Slavic phonemes:

CONSONANTS: velar k g x
dental t d s z
labial p b

SONANTS:	liquid	l	r		
	nasal	n	m		
VOWELS:	segment:	u	i	o	e
	diffuse:	+	+	-	-
	grave:	+	-	+	-

(Each vowel in both tense and lax variants)

In this report we shall not consider the redundancy rules that specify vowel archiphonemes. The correspondences are as follows:

$\bar{u}$	→	y	u	→	ъ
$\bar{\imath}$	→	i	i	→	ь
$\bar{o}$	→	a	o	→	ɔ
$\bar{e}$	→	e	e	→	ɛ

It is necessary to emphasize that we assume the segment u to be specified +flat before the application of rule (27). Monophthongization of the diphthongs ou and eu thus produces a long vowel $\overset{\circ}{\bar{u}}$ that is opposed to $\bar{u}$ by the specification +flat vs -flat.

We assume that at the outset all segments are specified -strident and -sharp.

2. Rules of the Morphophonemic Component

The rules of the morphophonemic component are given below; we draw attention to the fact that rules (2)-(5) constitute part of the Transformational Cycle in Polish.[2]

(1) $\begin{bmatrix}\text{+obstruent}\\ \text{+compact}\end{bmatrix} \rightarrow$ [-grave] in env: $C\ \underline{\underline{i}}\left(\left\{\begin{matrix}\underline{n}\\ \underline{r}\end{matrix}\right\}\right)\_\_\_\_\ \underline{\underline{o}}$

(2) Insert j in env: _____ + $\bar{V}$ + V

(3) $\begin{bmatrix}\text{-cons}\\ \text{+diff}\\ \text{-tense}\end{bmatrix} \rightarrow$ [-vocalic] in env: _____ + V[3]

(4) V → Ø in env: _____ + V

(5) Erase parentheses and return to rule (2); if there are no more parentheses, proceed to rule (6).

(6) $\begin{bmatrix}\text{+obstruent}\\ \text{+compact}\end{bmatrix} \rightarrow \begin{bmatrix}\text{+strident}\\ \text{-grave}\end{bmatrix}$ in env: $\_\_\_\_\_ \begin{bmatrix}\text{-cons}\\ \text{-grave}\end{bmatrix}$

(7) V → [+diffuse] in env: _____ s #

(8) [+obstruent] → ∅ in env: _____ #

(9) oi → ē in env: _____ [+cons][4]

(10) oi → ī elsewhere[4]

(11) e → o in env: $\left\{\begin{matrix}\text{[+compact]}\\ \text{[-grave]}\end{matrix}\right\}$ _____ l C[5]

(12) $\begin{bmatrix}\text{-diffuse}\\ \text{-tense}\end{bmatrix}$ L metathesize in env: _____C

(13) [-grave] → [-diffuse] in env: _____ r [+cons]

(14) [-grave] → $\begin{bmatrix}\text{+tense}\\ \text{+grave}\end{bmatrix}$ in env: _____ r $\begin{bmatrix}\text{+cons}\\ \text{-grave}\\ \text{-sharp}\end{bmatrix}$

(15) [-tense] → $\begin{bmatrix}\text{-diffuse}\\ \text{-grave}\end{bmatrix}$ in env: _____ l C

(16) [-tense] → [+grave] in env: $\begin{bmatrix}\text{+cons}\\ \text{+comp}\\ \text{-grave}\end{bmatrix}$ _____ l C

(17) C → [+sharp] in env: _____ $\begin{bmatrix}\text{-cons}\\ \text{-grave}\end{bmatrix}$

(18) ē → ō in env: $\begin{bmatrix}\text{+compact}\\ \text{-grave}\end{bmatrix}$ _____

(19) $\begin{bmatrix}\text{-cons}\\ \text{+diff}\end{bmatrix}$ → [+tense] in env: _____ j

(20) $\begin{bmatrix}\text{+obstruent}\\ \text{+compact}\end{bmatrix}$ → [-grave] in env: _____ $\begin{bmatrix}\text{-cons}\\ \text{-grave}\end{bmatrix}$

(21) $V \rightarrow \underline{e}$ in env: $\_\_\_\_\_ N \begin{Bmatrix} C \\ \# \end{Bmatrix}$

(22) $V \rightarrow \underline{o}$ in env: $N\ C \begin{Bmatrix} \underline{u} \\ \underline{i} \end{Bmatrix}$

(23) $\underline{ti} \rightarrow \emptyset$ in env: $+ \_\_\_\_\_ \#$

(24) $\underline{\bar{i}} \rightarrow [-\text{tense}]$ in env: $\_\_\_\_\_ \#$

(25) $\begin{Bmatrix} \underline{e} \\ \underline{o} \end{Bmatrix} \rightarrow [+\text{nasal}]$ in env: $\_\_\_\_\_ N \begin{Bmatrix} [+\text{obstruent}, +\text{continuant}] \\ \# \end{Bmatrix}$

(26) $N \rightarrow \emptyset$ in env: $N \_\_\_\_\_$

(27) $V \rightarrow [+\text{tense}]$ in env: $V \_\_\_\_\_$

(28) $\underline{j} \rightarrow \emptyset$ in env: $[-\text{cons}, +\text{comp}] \_\_\_\_\_ [-\text{cons}, +\text{comp}]$

(29) $V \rightarrow \emptyset$ in env: $\_\_\_\_\_ V$

(30) $[+\text{obstr}, -\text{grave}, +\text{contin}] \rightarrow [+\text{strident}]$

(31) $[+\text{obstr}, -\text{grave}] \rightarrow [+\text{compact}]$ in env: $\_\_\_\_\_ \underline{j}$

(32) $\underline{j} \rightarrow \emptyset$ in env: $[+\text{cons}] \_\_\_\_\_$

(33) $\underline{\overset{\vee}{j}} \rightarrow \underline{\overset{\vee}{z}}$

(34) $\underline{r} \rightarrow \underline{\overset{\vee}{z}}$

(35) $[+\text{obstr}, +\text{strid}, -\text{grave}] \rightarrow [+\text{compact}]$ in env: $\_\_\_\_\_ [+\text{obstr}, +\text{compact}, -\text{grave}]$

(36) $[+\text{obstr}, +\text{comp}, -\text{grave}] \rightarrow [+\text{strident}]$ in env: $[+\text{obstr}, +\text{comp}, -\text{grave}] \_\_\_\_\_$

(37) $\begin{bmatrix}+\text{obstr}\\-\text{strid}\\+\text{comp}\\-\text{grave}\end{bmatrix} \rightarrow \begin{bmatrix}+\text{strid}\\-\text{comp}\end{bmatrix}$

(38) $\begin{bmatrix}+\text{obstr}\\+\text{comp}\\-\text{grave}\end{bmatrix} \rightarrow [-\text{sharp}]$

(39) $[+\text{nasal}] \rightarrow \begin{bmatrix}\alpha\text{grave}\\ \beta\text{comp}\\ \gamma\text{sharp}\end{bmatrix}$ in env: $\_\_\_\_\_ \begin{bmatrix}+\text{obstr}\\ \alpha\text{grave}\\ \beta\text{comp}\\ \gamma\text{sharp}\end{bmatrix}$

(40) $\underline{\breve{e}} \rightarrow \underline{\breve{o}}$ in env: $\_\_\_\_\_ \begin{bmatrix}+\text{obstr}\\-\text{grave}\\-\text{sharp}\end{bmatrix}$

(41) $\left\{\begin{matrix}\underline{c}\\ \underline{\jmath}\end{matrix}\right\} \rightarrow [-\text{sharp}]$

(42) $\underline{o} \rightarrow \underline{\overset{\circ}{u}}$ in env: $\_\_\_\_\_ [+\text{obstruent}] + \left\{\begin{matrix}\underline{u}\\ \underline{i}\end{matrix}\right\}+$ [6]

(43) $\left\{\begin{matrix}\underline{u}\\ \underline{i}\end{matrix}\right\} \rightarrow \underline{e}$ in env: $\_\_\_\_\_ C\left\{\begin{matrix}\underline{u}\\ \underline{i}\end{matrix}\right\}$

(44) $\left\{\begin{matrix}\underline{u}\\ \underline{i}\end{matrix}\right\} \rightarrow \emptyset$

(45) $\begin{bmatrix}+\text{cons}\\-\text{grave}\end{bmatrix} \rightarrow [\alpha\text{sharp}]$ in env: $\_\_\_\_\_ \begin{bmatrix}+\text{cons}\\ \alpha\text{sharp}\end{bmatrix}$

(46) $\left\{\begin{matrix}\underline{t,} \rightarrow \underline{\acute{c}}\\ \underline{d,} \rightarrow \underline{\acute{\jmath}}\\ \underline{s,} \rightarrow \underline{\acute{s}}\\ \underline{z,} \rightarrow \underline{\acute{z}}\end{matrix}\right\}$

(47) $\begin{bmatrix}-\text{obstruent}\\-\text{vocalic}\end{bmatrix} \rightarrow \emptyset$ in env: $\_\_\_\_\_ + [+\text{cons}]$

(48) $\underline{w} \rightarrow \underline{v}$

(49) $\underline{\not{l}} \rightarrow \underline{w}$

(50) $\underline{l,} \rightarrow [-\text{sharp}]$ in env: $\_\_\_\_\_ \left\{\begin{matrix}[+\text{cons}]\\ [-\text{diffuse}]\\ [+\text{grave}]\end{matrix}\right\}$ [7]

(51) $\begin{bmatrix}+\text{cons}\\+\text{grave}\\-\text{comp}\end{bmatrix} \rightarrow [-\text{sharp}]$ in env: $\_\_\_\_\_ \left\{\begin{matrix}C\\ \#\end{matrix}\right\}$

3. Application of Rules

We apply these rules to the phomenic representations of the examples given above in section 1; the 3 Plural examples are given separately in section 5. We use the symbols $\hat{s}$ and $\hat{z}$ to emphasize the fact that /s/ and /z/ are -strident until application of rule (30) — cf. section 1.

1. mięso: mENŝ+o →17→ m,ENŝ+o →21→ m,eNŝ+o →25→ m,ęNŝ+o →26→ m,ęŝ+o →30→ m,ęso

2. mięs: mENŝ+oŝ →7→ mENŝ+uŝ →8→ mENŝ+u →17→ m,ENŝ+u →22→ m,oNŝ+u →25→ m,ǫNŝ+u →26→ m,ǫŝ+u →30→ m,ǫs+u →44→ m,ǫs

3. rękа: rONk+ō →21→ reNk+ō →39→ reŋka

4. ręce: rONk+oi →9→ rONk+ē →17→ rONk,+ē →20→ rONḱ,+ē →21→ reNḱ,+ē →37→ reNc,+ē →39→ ren,c,+ē →41→ ren,c+ē →45→ rence

5. rąk: rONk+oŝ →7→ rONk+uŝ →8→ rONk+u →22→ roNk+u →39→ roŋk+u →44→ roŋk

6. gęba: gONb+ō →21→ geNb+ō →39→ gemba

7. gębie: gONb+oi →9→ gONb+ē →17→ gONb,+ē →21→ geNb,+ē →39→ gem,b,e

8. świat: ŝwoit+oŝ →7→ ŝwoit+uŝ →8→ ŝwoit+u →9→ ŝwēt+u →17→ ŝw,ēt+u →30→ sw,ēt+u →40→ sw,ōt+u →44→ sw,ōt →45→ s,w,ōt →46→ św,ōt →48→ śv,at

9. świecie: ŝwoit+oi →9→ ŝwēt+ē →17→ ŝw,ēt,+ē →30→ sw,ēt,+ē →45→ s,w,ēt,+ē →46→ św,ēć+ē →48→ śv,eće

10. kara: kōr+ō → kara

11. karze: kōr+oi →9→ kōr+ē →17→ kōr,+ē →34→ kōž,+ē →38→ kaže

12. pies: piŝ+oŝ →7→ piŝ+uŝ →8→ piŝ+u →17→ p,iŝ+u →30→ p,is+u →43→ p,es+u →44→ p,es

13. psa: piŝ+ō →17→ p,iŝ+ō →30→ p,is+ō →44→ p,s+ō →51→ psa

14. sen: ŝun+oŝ [< *supn+os] →7→ ŝun+uŝ →8→ ŝun+u →30→ sun+u →43→ sen+u →44→ sen

15. śnie: ŝun+oi →9→ ŝun+ē →17→ ŝun,+ē →30→ sun,+ē →44→ sn,+ē →45→ s,n,+ē →46→ śn,e

16. Bóg: bog+oŝ →7→ bog+uŝ →8→ bog+u →42→ bu̯g+u →44→ bu̯g → buk

17. Boże: bog+e →6→ boǰ+e →17→ boǰ,+e →33→ bož,+e →38→ bože

18. kto: kuto →44→ kto

19. któż: kuto+gi →6→ kuto+ǰi →17→ kuto+ǰ,i →33→ kuto+ž,i →38→ kuto+ži →42→ kutu̯+ži →44→ ktu̯+ž → ktuš

20. anioł: ōnel+oŝ →7→ ōnel+uŝ →8→ ōnel+u →17→ ōn,el+u →40→ ōn,ol+u →44→ ōn,ol →49→ an,ow

21. aniele: ōnel+oi →9→ ōnel+ē →17→ ōn,el,+ē →50→ an,ele

22. lew: liw+oŝ →7→ liw+uŝ →8→ liw+u →17→ l,iw+u →43→ l,ew+u →44→ l,ew →48→ l,ev →50→ lev → lef

23. lwa: liw+ō →17→ l,iw+ō →44→ l,w+ō →48→ l,v+ō →50→ lva

24. las: lēŝ+oŝ →7→ lēŝ+uŝ →8→ lēŝ+u →17→ l,ēŝ+u →30→ l,ēs+u →40→ l,ōs+u →44→ l,ōs →50→ las

25. lesie: lēŝ+oi →9→ lēŝ+ē →17→ l,ēŝ,+ē →30→ l,ēs,+ē →46→ l,ēś+ē →50→ leśe

26. mucha: moux+ō →27→ mo̊ux+ō →29→ muxa

27. musze: moux+oi →9→ moux+ē →17→ moux,+ē →20→ moux́,+ē →27→ mo̊ux́,+ē →29→ mů́x,+ē →30→ mů́š,+ē →38→ muše

28. chłopiec: xolp+ik+oŝ →1→ xolp+iḱ+oŝ →7→ xolp+iḱ+uŝ →8→ xolp+iḱ+u →12→ xlop+iḱ+u →17→ xlop,+iḱ+u →37→ xlop,+ic+u →43→ xlop,+ec+u →44→ xlop,+ec →49→ xwop,ec

29. chłopca: xolp+ik+ō →1→ xolp+iḱ+ō →12→ xlop+iḱ+ō →17→ xlop,+iḱ+ō →37→ xlop,+ic+ō →44→ xlop,+c+ō →49→ xwop,+c+ō →51→ xwopca

30. chłopcze: xolp+ik+e →6→ xolp+iǩ+e →12→ xlop+iǩ+e →17→ xlop,+iǩ,+e →38→ xlop,+iǩ+e →44→ xlop,+ǩ+e →49→ xwop,+ǩ+e →51→ xwopče

31. prości: prôst+oi →10→ prôst+ī →17→ prôst,+ī →30→ prost,+ī →45→ pros,t,+ī →46→ prośći

32. głusi: gloux+oi →10→ gloux+ī →17→ gloux,+ī →20→ gloux́,+ī →27→ glo̊ux́,+ī →29→ glů́x,+ī →37→ glů́s,+ī →46→ glusi[8]

33. piekę: ((pek+e)+om) →5→ (pek+e+om) →4→ (pek+om) →5→
pek+om →17→ p,ek+om →21→ p,ek+em →25→ p,ek+ęm
→26→ p,ekę

34. piecze: ((pek+e)+ti) →5→ (pek+e+ti) →5→ pek+e+ti →6→
peč+e+ti →17→ p,eč,+e+ti →23→ p,eč,+e →38→ p,eče

36. niosę: ((neŝ+e)+om) →5→ (neŝ+e+om) →4→ (neŝ+om) →5→
neŝ+om →17→ n,eŝ+om →21→ n,eŝ+em →25→ n,eŝ+ęm
→26→ n,eŝ+ę →30→ n,es+ę →40→ n,osę

37. niesie: ((neŝ+e)+ti) →5→ (neŝ+e+ti) →5→ neŝ+e+ti →17→
n,eŝ,+e+t,i →23→ n,eŝ,+e →30→ n,es,+e →46→ n,eśe

39. nióśy: neŝ+l+oŝ →7→ neŝ+l+uŝ →8→ neŝ+l+u →17→ n,eŝ+l+u
→30→ n,es+l+u →40→ n,os+l+u →42→ n,ŭs+l+u →44→
n,ŭs+l →49→ n,usw

40. idę: ((id+e)+om) →5→ (id+e+om) →4→ (id+om) →5→ id+om
→21→ id+em →25→ id+ęm →26→ idę

41. idzie: ((id+e)+ti) →5→ (id+e+ti) →5→ id+e+ti →17→
id,+e+t,i →23→ id,+e →46→ iźe

43. noszę: ((noŝ+Ī+Ī)+om) →4→ ((noŝ+Ī)+om) →5→ (noŝ+Ī+om)
→2→ (noŝj+Ī+om) →4→ (noŝj+om) →5→ noŝj+om →17→
noŝ,j+om →21→ noŝ,j+em →25→ noŝ,j+ęm →26→ noŝ,j+ę
→30→ nos,j+ę →31→ noš,j+ę →32→ noš,+ę →38→ nošę

44. nosicie: ((noŝ+Ī+Ī)+te) →4→ ((noŝ+Ī)+te) →5→ (noŝ+Ī+te)
→5→ noŝ+Ī+te →17→ noŝ,+Ī+t,e →30→ nos,+Ī+t,e
→46→ nośiće

46. obrazować: obrōẑ+ou+ō+tĪ →3→ obrōẑ+ow+ō+tĪ →17→ obrōẑ +ow+ō+t,Ī →24→ obrōẑ+ow+ō+t,i →30→ obrōz+ow+ō+t,i →44→ obrōz+ow+ō+t, →46→ obrōz+ow+ō+ć →48→ obrazować

47. obrazujecie: ((obrōẑ+ou+ō+e)+te) →2→ ((obrōẑ+ouj+ō+e)+te) →4→ ((obrōẑ+ouj+e)+te) →5→ (obrōẑ+ouj+e+te) →5→ obrōẑ+ouj+e+te →17→ obrōẑ+ouj+e+t,e →27→ obrōẑ+o̊uj +e+t,e →29→ obrōẑ+ůj+e+t,e →30→ obrōz+ůj+e+t,e →46→ obrazujeće

48. robić: orb+Ī+tĪ →12→ rob+Ī+tĪ →17→ rob,+Ī+t,Ī →24→ rob,+Ī+t,i →44→ rob,+Ī+t, →46→ rob,ić

49. rób: ((orb+Ī+Ī)+Ī+#) →4→ ((orb+Ī)+Ī+#) →5→ (orb+Ī+Ī+#) →4→ (orb+Ī+#) →5→ orb+Ī+# →12→ rob+Ī+# →17→ rob,+Ī+# →24→ rob,+i+# →42→ r̊ub,+i+# →44→ r̊ub,+# →51→ rub → rup

50. widzę: ((wĪd+ē+Ī)+om) →4→ ((wĪd+Ī)+om) →5→ (wĪd+Ī+om) →2→ (wĪdj+Ī+om) →4→ (wĪdj+om) →5→ wĪdj+om →17→ w,Īd,j+om →21→ w,Īd,j+em →25→ w,Īd,j+ęm →26→ w,Īd,j+ę →31→ w,Īǵ,j+ę →32→ w,Īǵ,+ę →37→ w,Īʒ,+ę →41→ w,Īʒ+ę →48→ v,iʒę

51. widzicie: ((wĪd+ē+Ī)+te) →4→ ((wĪd+Ī)+te) →5→ (wĪd+Ī+te) →5→ wĪd+Ī+te →17→ w,Īd,+Ī+t,e →46→ w,Īʒ́+Ī+će →48→ viʒ́ić́e

52. jeżdżę: ((jeẑd+Ī+Ī)+om) →4→ ((jeẑd+Ī)+om) →5→ (jeẑd +Ī+om) →2→ (jeẑdj+Ī+om) →4→ (jeẑdj+om) →5→ jeẑdj+om →17→ jeẑd,j+om →21→ jeẑd,j+em →25→ jeẑd,j+ęm →26→ jeẑd,j+ę →30→ jezd,j+ę →31→ jezǵ,j+ę →32→ jezǵ,+ę →35→ jeǯǵ,+ę →36→ jeǯǰ,+ę →38→ jeǯǰę

53. jeździcie: ((jeẑd+Ī+Ī)+te) →4→ ((jeẑd+Ī)+te) →5→ (jeẑd+Ī+te) →5→ jeẑd+Ī+te →17→ jeẑd,+Ī+t,e →30→ jezd,+Ī+t,e →45→ jez,d,+Ī+t,e →46→ jeźʒiće

54. strzygę: ((ŝtrĪg+e)+om) →5→ (ŝtrĪg+e+om) →4→ (ŝtrĪg+om) →5→ ŝtrĪg+om →17→ ŝtr,Īg+om →21→ ŝtr,Īg+em →25→ ŝtr,Īg+ęm →26→ ŝtr,Īg+ę →30→ str,Īg+ę →34→ stǯ,Īg+ę →38→ stǯĪg+ę [two special rules must now apply to derive phonetic transcription: (A) $\underline{\bar{I}} \rightarrow \underline{\bar{u}}$ after "hard" consonants, and (B) $\underline{ǯ} \rightarrow \underline{š}$ after voiceless obstruents. Thus we derive: stǯĪg+ę →A→ stǯūg +ę →B→ stšūg+ę stšygę]

55. strzyżecie: ((ŝtrĪg+e)+te) →5→ (ŝtrĪg+e+te) →5→ ŝtrĪg +e+te →6→ ŝtrĪǰ+e+te →17→ ŝtr,Īǰ+e+t,e →30→ str,Īǰ,+e+t,e →33→ str,Īǯ,+e+t,e →34→ stǯ,Īǯ+e+t,e →38→ stǯĪǯ+e+t,e →46→ stǯĪǯ+e+će →A→ stǯūǯ+e+će →B→ stšūǯ+e+će stšyżeće

56. pić: pij+tĪ →17→ p,ij+t,Ī →19→ p,Īj+t,Ī →24→ p,Īj+t,i →44→ p,Īj+t, →46→ p,Īj+ć →47→ p,ić

57. pijecie: ((pij+e)+te) →5→ (pij+e+te) →5→ pij+e+te →17→ p,ij+e+t,e →19→ p,Īj+e+t,e →46→ p,ijeće

58. myć: muj+tĪ →17→ muj+t,Ī →19→ mūj+t,Ī →24→ mūj+t,i →44→ mūj+t, →46→ mūj+ć →47→ mū+ć myć

59. myjecie: ((muj+e)+te) →5→ (muj+e+te) →5→ muj+e+te →17→ muj+e+t,e →19→ mūj+e+t,e →46→ myjeće

60. człon: keln+oŝ →6→ čeln+oŝ →7→ čeln+uŝ →8→ čeln+u →11→ čoln+u →12→ člon+u →44→ člon →49→ čwon

61. głod: gold+oŝ →7→ gold+uŝ →8→ gold+u →12→ glod+u →44→ glod →49→ gwod → gwot

62. brzeg: berg+oŝ →7→ berg+uŝ →8→ berg+u →12→ breg+u →17→ br,eg+u →34→ bž,eg+u →38→ bžeg+u →44→ bžeg → bžek

63. mleć: mel+tĪ →12→ mle+tĪ →17→ ml,e+t,Ī →24→ ml,e+t,i →44→ ml,e+t, →46→ ml,e+ć →50→ mleć

64. mielecie: ((mel+e)+te) →5→ (mel+e+te) →5→ mel+e+te →17→ m,el,+e+t,e →46→ m,el,+e+će →50→ m,eleće

65. kiełbasa: kulbōŝ+ō →15→ kelbōŝ+ō →17→ k,elbōŝ+ō →30→ k,elbōs+ō →49→ k,ewbasa

66. dobrego: dobr+ō+jego →28→ dobr+ō+ego →29→ dobrego

67. kochacie: ((kox+ōj+ē)+te) →5→ (kox+ōj+ē+te) →5→ kox +ōj+ē+te →17→ kox+ōj+ē+t,e →18→ kox+ōj+ō+t,e →28→ kox+ō+ō+t,e →29→ kox+ō+t,e →46→ koxaće

4. Colloquial Pronunciation of Non-Nasal [ɛ]

In order to account for the colloquial pronunciation of non-nasal [ɛ] when the spelling is ę, we require one additional rule. This rule applies optionally (the constraints on the application of the rule are apparently extralinguistic; thus, for example, stage performers will not apply the rule on stage, but in everyday speech they apply the rule regularly:

$(52)_{opt}$ ę → [-nasal] in env: _____ #

If the speaker decides not to apply this rule, then the form niosę, for example, will be pronounced [n,osę], as derived above in example 36. If, however, the speaker does decide to apply this rule, the form niosę will be pronounced [n,ose]:

n,os+ę →52→ n,os+e → n,ose

5. The 3 Plural Ending

It seems reasonable to assume from the work presented thus far that the Polish phonemic forms are essentially identical with the phonemic forms that historical linguists postulate for Proto-Slavic. Such an assumption is confirmed by the results of our work on Russian.

In our work on Russian we found that the most general formulation of the 3 Plural verb ending (phonetically at and ut) is /n+tu/.[9] This ending is also the most general formulation of 3 + Plural in OCS and, of course, in Proto-Slavic.[10] We would like to suggest that although the Proto-Slavic base forms have been for the most part retained in Polish, the 3 Plural ending /n+ti/ has not been retained but has been replaced by /on+ti/.

We derive below the 3 Plural forms listed in section 1:

35. pieką: ((pek+e)+on+ti) →5→ (pek+e+on+ti) →4→ (pek+on+ti) →5→ pek+on+ti →17→ p,ek+on+t,i [rules (21) and (22) apply vacuously; note, however, that rule (22) will not apply if we do not retain the Proto-Slavic 3rd Person particle /ti/] →23→ p,ek+on →25→ p,ek+ǫn →26→ p,ekǫ

38. niosą: ((neŝ+e)+on+ti) →5→ (neŝ+e+on+ti) →4→ (neŝ+on+ti) →5→ neŝ+on+ti →17→ n,eŝ+on+t,i →23→ n,eŝ+on →25→ n,eŝ+ǫn →26→ n,eŝ+ǫ →30→ n,es+ǫ →40→ n,osǫ

42. idą: ((id+e)+on+ti) →5→ (id+e+on+ti) →4→ (id+on+ti) →5→ id+on+ti →17→ id+on+t,i →23→ id+on →25→ id+ǫn →26→ idǫ

45. nosza: ((noŝ+Ī+Ī)+on+ti) →4→ ((noŝ+Ī)+on+ti) →5→ (noŝ+Ī +on+ti) →2→ (noŝj+Ī+on+ti) →4→ (noŝj+on+ti) →5→ noŝj+on+ti →17→ noŝ,j+on+t,i →23→ noŝ,j+on →25→ noŝ,j+ǫn →26→ noŝ,j+ǫ →30→ nos,j+ǫ →31→ noš,j+ǫ →32→ noš,+ǫ →38→ nošǫ

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Footnotes

1. I am indebted to my friends and colleagues from Harvard University, Robert A. Rothstein and E. W. Browne, both of whom have read parts of this report and have made many valuable suggestions. In particular I would like to thank E. W. Browne for explaining to me that the Indo-European Nom. Masc. Sing. ending os must be retained in Slavic in order to account for the Baudouin de Courtenay Palatalization.

2. Morris Halle and I have worked jointly on the problem of the Baudouin de Courtenay Palatalization – rule (1). For details on the motivation for formulating the rule as shown here and for requiring rule (1) to apply before the Transformational Cycle, see M. Halle and T. M. Lightner, Relative Chronology and Synchronic Order of Rules (in preparation). The treatment of dental palatalization presented in this report – rule (31) – is a slightly adapted version of the one that Halle and I will present in that paper.

3. Lax $\left\{\begin{matrix}u\\ i\end{matrix}\right\}$ also become glides in env: $\overline{V}$ + _____. This rule will derive the j in znać, for example, from the morphophonemic representation /znōi+tī/. Note that this j does not appear in phonetic transcription because of the application of rule (47): znaj+ć →47→ znać.

It is important to note that these two rules predict glides only when a vowel follows/ precedes lax $\left\{\begin{matrix}u\\ i\end{matrix}\right\}$ across a morpheme boundary. The prediction of glides elsewhere is handled by two Morpheme Structure Rules, one of which predicts glides before vowels (dwór < /duor+os/), the other of which predicts glides in root final position (żyć < /giu+tī/).

4. Why the Loc. Sg. ending /oi/ should have developed to ě and not to ī remains an unexplained puzzle.

5. This rule is taken from Roman Jakobson, Remarques, TCLP, II, 21 (1929): "Dans le parler slave oriental, les voyelles prépalatales de la diphtongue avec l se sont labialisées, quoi que ce fût qui précédât; dans les parlers auxquels remontent le polonais, le tchécoslovaque et les langues sud-slaves, la labialisation n'a pas eu lieu après les consonnes labiales."

6. Some constraint must obviously be placed on the application of this rule. Cf., e.g., Imperative proś (and not *prós). The current descriptions of this alternation are vague and unrevealing. See, e.g., Stanisław Szober, Gramatyka języka polskiego (Warszawa, 1953), pp. 35-37. For an account of doublets like bóle ~ bole, chłódzić ~ chłodzić, etc., see Klemensiewicz, Lehr-Spławiński, Urbańczyk, Gramatyka historyczna języka polskiego (Warszawa, 1955), Sec. 29. Forms of the verb mówić (from the PS root /mulw/) 'to speak' are apparently exceptional; cf. the regular substantive mowa (Gen. Pl. mów) 'speech.'

7. There is a difference of opinion among my colleagues as to how the letter ł is pronounced in Polish. Late phonetic rules in all languages naturally show wide variation, even in the idiolect of a single speaker. In formulating rule (50) I follow Szober, op. cit., p. 17, "Litera ł przed a, o, u (ó) oznacza spółgłoskę ł twardą, np. las, lot, lud, łódź."

8. Note that the Nom. Masc. Pers. Pl. forms do not undergo application of rule (30). We quote from Klemensiewicz et al., op. cit., p. 140: "Starsze polskie ś rozwija się w ś przed końcówka M. l mn. rzeczownika, przymiotnika, liczebnika i zaimka męskoosobowego, np. Włosi < stp. Włoszy < *volš'i; głusi < stp. gluszy < *gluš'i."

9. See T. M. Lightner, The third person plural ending in Russian, IJSLP (in press).

10. We shall not discuss the alternation of u ~ i other than to point out that jers in final position are weak and hence subject not only to truncation but also to interchange.

D. REDUCTION OF LONG i IN RUSSIAN IMPERATIVE, INFINITIVE, AND 2 SINGULAR MORPHEMES

The phonemic form of the Russian Imperative is /ī+#/ (but /ū+#/ after velars), of the Infinitive /tī/, and of the 2 Singular /sī/. In all three morphemes, the terminal long /ī/ is obligatorily reduced to short /i/ when unstressed or not after a consonant cluster.

For example (all forms in postcycle representation):

1. gotów+Ī+#+te → gotów+i+#+te → gotów,+i+#+t,e → gotów,+#+t,e → gotov,t,e
2. krík+n+Ī+#+te → kr,íkn,it,e [no reduction because of consonant cluster]
3. xod+Í+#+te → xod,ít,e [no reduction because of stress]
4. pro+kit+Í+#+te → pro+čit+Í+#+te → pro+č,it,+Í+#+t,e → pro+č,t,+Í+#+t,e → prač,t,ít,i [no reduction because of stress]
5. xod+Í+tĪ → xod+Í+ti → xod,ít,
6. pro+kít+tĪ → pro+čít+tĪ → pro+čít+ti → pro+č,ít+t,i → pro+č,ét+t,i → pro+č,ét+t, → proč,ést,
7. nes+tÍ → n,ist,í [no reduction because of stress]
8. eb+é+sĪ → jeb+é+sĪ → jeb+é+xĪ → jeb+é+šĪ → jeb+é+ši → jeb,+é+š,i → jeb,+é+š, → jeb,+é+š → jeb,+ó+š → jɪb,óš

In examples 1, 5, 6, and 8, the short /i/'s derived from the long /ī/'s are weak

jers in final position and therefore drop after sharping the preceding consonants. Note that in example 6 the final weak jer also serves to strengthen the preceding jer of the root /kit/; this strong jer, of course, is manifested phonetically as e.

Terminal long $\{\bar{i}, \bar{u}\}$ is optionally reduced to short $\{i, u\}$ in other forms that satisfy the environmental conditions stated above. The doublets ili ~ il' and by ~ b, for example, are derived from /īlī/ and /bū/, respectively.[1]

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References

1. For a diachronic description and more examples, see Šaxmatov, Očerk drevnešego perioda istorii russkogo jazyka (Petrograd, 1915), Sec. 360, pp. 222-224.

E. sr/zr CLUSTERS IN OLD CHURCH SLAVONIC

One of the early phonetic rules in OCS will be as follows:

$$\text{Insert} \begin{bmatrix} +\text{obstr} \\ +\text{cons} \\ -\text{grave} \\ -\text{cont} \\ \alpha\text{voice} \end{bmatrix} \quad \text{in env:} \quad \begin{bmatrix} +\text{obstr} \\ +\text{cons} \\ -\text{grave} \\ +\text{cont} \\ \alpha\text{voice} \end{bmatrix} \text{\_\_\_\_\_ r}$$

We give some examples of forms to which this rule applies:

OCS	Phonemic	Gloss
сєстра	/sesr/	'sister'
страхъ	/srōx/	'terror'
издрєшти	/īz+rek/	'to express'
бєздразоума	/bez+rōz+oum/	'without understanding'
ноздри[1]	/nozr/	'nostrils'

Forms such as срамъ 'shame,' зракъ 'sight' etc. do not have the $/\{^{s}_{z}\}$ r/ cluster in their underlying forms. Thus срамъ, зракъ, e.g., are derived from /sorm/ and /zork/.

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Footnotes

1. The etymology of this form is not clear (cf. Eng. nostril). See P. Diels, Altkirchenslavische Grammatik (Carl Winters, Heidelberg, 1932), Sec. 43, Note 3, and the publications cited therein.

F. SOME REMARKS ON ELEMENTARY TRANSFORMATIONS

Underlying every grammatical transformation T is a restricting class Q and an elementary transformation t.[1] Q contains m sequences of strings $W_1^j, \ldots, W_r^j$, $1 \leq j \leq m$, and limits the domain of T. A transformation is applicable to a P-marker K only if the string Z of terminal symbols uniquely associated with K can be divided into a sequence $Z_o, \ldots, Z_r$ of strings called the proper analysis of Z with respect to K and Q, where Z_o is always the identity element and, for at least one j, each Z_i, $1 \leq i \leq r$, can be analyzed as W_i^j with respect to K. The effect of the elementary transformation t, a formal operation defined on the r terms of the proper analysis, is the addition, the deletion, the rearrangement of these terms and/or constants or some combination of these operations.

We define the operation t over the r terms of the proper analysis as $t(i, Z_1, \ldots, Z_r) = V_i$, $1 \leq i \leq r$, where V_i is a string of terms of the proper analysis and/or constants. Each elementary transformation t consists of a compound of one or more primitive transformations with an associated rule of derived constituent structure. Let t_1 and t_2 be two primitive transformations; we now define the elementary transformation t to be the compound $t_2(t_1)$, where $t(i, Z_1, \ldots, Z_r) = t_2(i, Y_1, \ldots, Y_r)$ and $Y_j = t_1(j, Z_1, \ldots, Z_r)$. In this way we can define an elementary transformation $t = t_n(t_{n-1}(\ldots(t_1))\ldots)$ for some arbitrary n, although the greatest amount of compounding thus far required is for n = 2. The rule of derived constituent structure associated with each of the primitive transformations states how the P-marker, or tree structure, on which this transformation operates is to be altered. The claim made here is that three primitive transformations of adjunction, substitution, and conjunction are necessary and sufficient for the syntactical component of a transformational grammar.

The adjunction primitive transformation α has the effect of adjoining to the left (and right) of each term Z_i, $1 \leq i \leq r$, of the proper analysis some string $Y_{2i-1}(Y_{2i})$. Y_{2i-1} (the following discussion applies equally to Y_{2i}) may consist of terms of the proper analysis, constants or combinations of these two. For an r-termed proper analysis we define the operation α as $\alpha(Z_1, \ldots, Z_r) = (Y_1, Y_2, \ldots, Y_{2r-1}, Y_{2r})$, where Y_{2i-1} is adjoined to the left of the term Z_i and Y_{2i} is adjoined to the right. If Y_{2i-1} contains some term Z_j of the proper analysis, this term with all of its constituent structure up to and including the string of symbols W_j into which Z_j was analyzed is duplicated, and this duplication is adjoined as part of the string Y_{2i-1}. The original term Z_j with its constituent structure remains intact. If $Y_{2i-1} = X_1 Z_o X_2$, then $X_1 = 0 = X_2$; this is the case of adjoining an empty string to the left of the term Z_i. Each symbol of an adjoined string Y_{2i-1} is now dominated by the symbol – call it V_k – which dominates the left-most symbol of W_i, the string of symbols into which Z_i was analyzed. This means that for each of the constant terms in Y_{2i-1} there is a line in the P-marker attached

directly from V_k to the constant form. For each term Z_j of the proper analysis in Y_{2i-1} there is a line in the P-marker from V_k to each symbol of the string W_j, where this string consists of the top nodes of the constituent structure associated with Z_i in its adjoined position.

As an example, we have a simplified version of the Complement-Movement Transformation of English.[2]

$$Q = \underset{W_1}{X} - \underset{W_2}{Comp} - \underset{W_3}{NP} - \underset{W_4}{Y} \qquad t = a$$

$$a(Z_1,Z_2,Z_3,Z_4) = (Z_o,Z_o,Z_o,Z_o,Z_o,Z_2,Z_o,Z_o)$$

Diagrams 1 and 2 show the simplified P-markers before and after the application of the transformation.

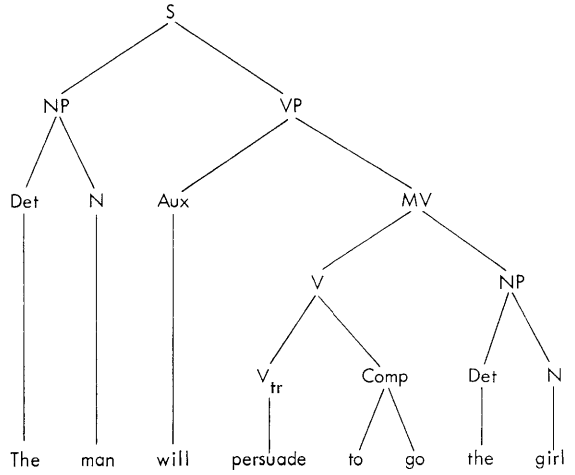

Diagram 1

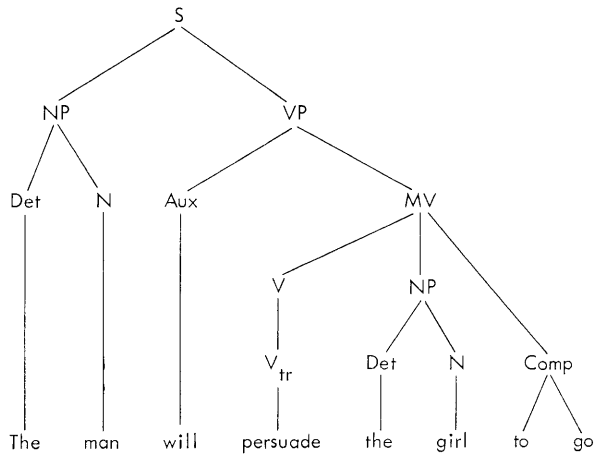

Diagram 2

The substitution primitive transformation σ has the effect of replacing each term Z_i of the proper analysis by some string Y_i. This string may consist of terms of the proper analysis, constants or combinations of these two. If $Y_i = X_1 Z_o X_2$, then $X_1 = 0 = X_2$; this is the case of substituting the identity element for some term Z_i of the proper analysis, and the effect is to delete the term Z_i. We define the operation σ as $\sigma(Z_i, \ldots, Z_r) = (Y_i, \ldots, Y_r)$. If some string $Y_i = Z_i$, then each symbol of Z_i is replaced by itself and there is no alteration in the constituent structure as a result of the operation of σ on the term Z_i. If Y_i contains some term Z_j of the proper analysis, this term and its constituent structure are duplicated and carried over in the manner described for the operation a. In this case we place the condition on W_i, the string into which the term Z_i has been analyzed, that it be only a single symbol. The constituent structure of the term Z_i up to but not including the single symbol W_i is now deleted from the P-marker and W_i now dominates the substituted string Y_i in the same sense as V_k dominated the string Y_{2i-1}

in the discussion above.

As an example, consider the Agent-Deletion Transformation of English.

$$Q = X - Agnt - Y \qquad t = \sigma$$
$$W_1 \quad W_2 \quad W_3 \qquad \sigma(Z_1, Z_2, Z_3) = (Z_1, Z_o, Z_3)$$

Diagrams 3 and 4 show the source and derived P-markers, respectively.[3]

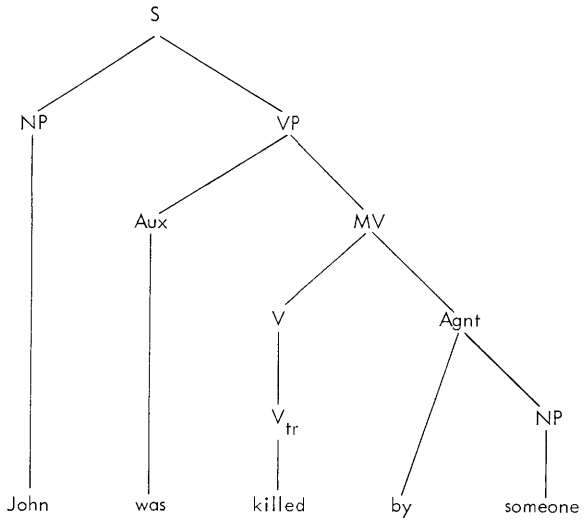

Diagram 3

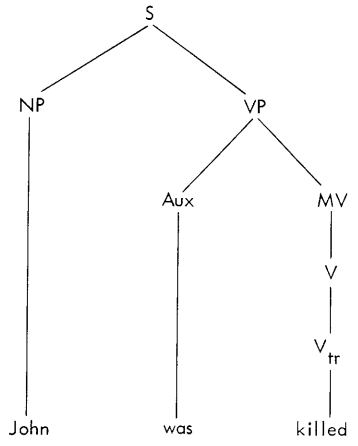

Diagram 4

The conjunction primitive transformation κ has the effect of adjoining some string Y_{Ri} to the right of each term Z_i of the proper analysis. This operation is not, however, a special case of the adjunction operation, as will be obvious from the associated rule of derived constituent structure. The string Y_{Ri} consists of some term Z_j of the proper analysis optionally preceded by a conjunction constant C. If $Y_{Ri} = Z_o$, the empty string is adjoined and there is no concomitant change in the P-marker. We define the operation κ as $\kappa(Z_1, \ldots, Z_R) = (Y_{R1}, \ldots, Y_{Rr})$. If the adjoined term Z_j is not Z_o, Z_j with all of its constituent structure up to but not including the string of symbols W_j into which Z_j was analyzed is duplicated and carried over into the adjoined position. The rightmost symbol of the string W_i now dominates the adjoined string Y_{Ri} in the sense discussed for the first two operations.

As an example, we have the Verb-Duplication Transformation of English

$$Q = X - V_{intr} - Y \qquad t = \kappa$$
$$W_1 \quad W_2 \quad W_3 \qquad \kappa(Z_1, \ldots, Z_r) = (Z_1, \text{And } Z_2, Z_3)$$

The source and derived P-markers are represented in Diagrams 5 and 6, respectively.

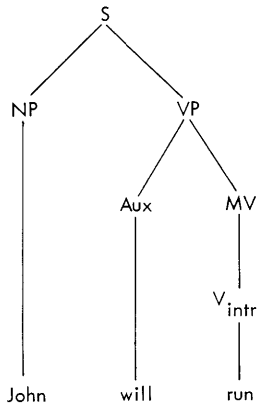

Diagram 5

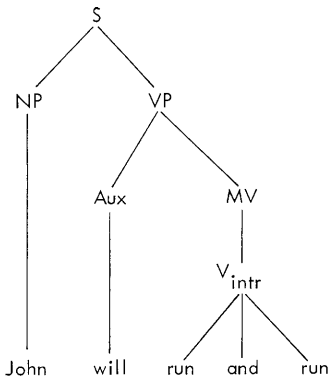

Diagram 6

An investigation beyond the scope of this report would show that the effect on the terms of the proper analysis and the resulting derived constituent structure produced by these three primitive transformations are satisfactory with respect to the presystematic requirements placed on the grammar. Consideration of the formulation of these operations will show that no two can be combined to produce just the effect of the third. We may thus conclude that these three primitive transformations are necessary for at least a transformational grammar of English. To show that they are sufficient would require proving that they effect all desired mappings of P-markers onto P-markers. This, unfortunately, we cannot state a priori. We can, however, state that we have been unable thus far to motivate a fourth primitive transformation.

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References

1. For a more detailed discussion of the characterization of and motivation for transformations, see N. Chomsky, Logical Structure of Linguistic Theory, 1955, Microfilm available in Hayden Library, M.I.T., and B. Fraser, The Linguistic Framework for a Sentence Recognition and Analysis Routine, Working Paper W-6266, The Mitre Corporation, Bedford, Massachusetts, 1963.

2. The transformation actually is a compound of two primitive elementary transformations, the second of which deletes the symbol "Comp" from its original position. For the moment we shall ignore this difficulty.

3. The symbol "Agnt" is not erased by this transformation but by a general rule of the grammar which states that any nonterminal symbol not dominating a string of symbols is automatically deleted.