Word order variation and comprehensiveness of centre embedding
(evidence from Ukrainian)

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Finding appropriate models and representation formalisms for word order variation is often essential for the development of accurate parsers, especially for languages with a large degree of such variation, like most of the Slavic languages. In this paper we examine different word order types, in particular – the *direct* and *unconfigurational* word order (that have computational complexity of context-free languages), and the *unprojective* word order (which is computationally more complex and is used mainly in spontaneous speech and poetry, but is also present in 17th-century baroque-style chronicles). A representation framework based on isomorphic transformations of constituent system trees is proposed for different word order types. Further this framework is used for an analysis of comprehensiveness of centre-embedded constructs. It is suggested that up to 3 (or sometimes 4) levels of centre embedding can be still comprehensible, which agrees with V.Yngve's depth hypothesis. Examples of incomprehensible sentences with 1 and 2 levels of centre embedding of subordinate clauses (of the type "**The rat the cat the dog chased bit ate the cheese*") – are shown to have incoherent morphological features in their phrase structure. Comprehensiveness of such sentences is distorted by the incoherence in feature structures, but it is not directly related to the number of levels of centre embedding in them.

Introduction. Models and representation formalisms of word order variation are important components of accurate syntactic parsers for speech and language applications, such as information retrieval or machine translation systems. On the other hand, languages with a high degree of word order variation provide evidence for analysis of several interesting linguistic and cognitive phenomena, such as comprehensiveness of centre-embedded sentences and phrases, stylistic distribution of sentences with different word order types, etc. In this paper we present and analyse data of word order variation in Ukrainian, where a relatively large degree of such variation is acceptable (as well as in many other Slavic languages). We show how the presented analysis allows explaining comprehensive limits of different levels of centre embedding in various types of constructs. Where it is possible, we try to present the data in a way that is independent from a particular linguistic theory, so it is available for analysis in different syntactic frameworks.

Types of word order variation. Word order in Ukrainian declarative sentences can be characterised by the following rules:

1. ***Direct word order***. There is an unmarked, most neutral order of constituents for any type of phrases. On the sentence level this is an 'SVO' order. In noun phrases adjectives precede nouns; in prepositional phrases prepositions precede NPs, e.g., as in sentence (1):

(1) *Збираюся в далеку дорогу*[1] (V [prep Adj N]$_{obj}$)
I.prepare$_{pres.sing.p1}$ [in$_{prep/acc}$ long$_{Adj.acc.sing.fem}$ journey$_{Noun.acc.sing.fem}$]
I prepare for a long journey

2. ***Unconfigurational word order***. Any constituents in phrases on any level can be permutated freely (with a few exceptions), e.g., for the 3 components on the sentence level (e.g., subject, verb and object / adjunct) all 6 orderings are possible. Any permutation of constituents within a phrase will change the direct word order into an unconfigurational word order, e.g., when a verb follows an object on the sentence level:

(2) *В далеку дорогу збираюся* ([prep Adj N]$_{obj}$ ⇆ V)

Another example, when an adjectives follows a noun (the predicative meaning of the adjective is increased in this case).

(3) *Збираюся в дорогу далеку* (V [prep [N ⇆Adj]])

Permutations on different levels are independent of each other, so several permutations can occur in a sentence:

(4) *В дорогу далеку збираюся* ([prep [N ⇆Adj]] ⇆ V)

Prepositions, however, cannot exchange places with the following NPs in prepositional phrases:

(5) **Збираюся далеку дорогу в* (V $_{PP}$[[Adj N] ⇆ prep])

(6) **Далеку дорогу в збираюся* ($_{PP}$[[Adj N] ⇆ prep] ⇆ V)

[1] Ukrainian uses Cyrillic alphabet. I prefer not to transliterate Ukrainian examples from Cyrillic, and I apologize, it this causes any difficulty to readers of this paper.

A set of synonymous sentences with unconfigurational word order can be derived from a sentence with the direct word order by systematic permutation of constituents in each of phrases, where the permutation is allowed.

The use of a direct word order or a specific unconfigurational word order is generally motivated by the distinction of a theme / rheme (given / new information) in the sentence [Pumpyanskiy, 1974], but in many cases, there is no direct correspondence between the word order and the theme/ rheme distinction.

3. ***Unprojective word order.*** This type of word order characterises *discontinuous phrases*. Such phrases are derived from sentences with direct word order, when "external" constituents, which do not belong to the phrase, are inserted between its constituents:

(7) *В далеку збираюся дорогу* ($_{PP}$[prep Adj… V …N])

(8) *В дорогу збираюся далеку* ($_{PP}$[prep N… V … ⇆Adj])

Within a clause any unprojective permutation is allowed that still preserves the syntactic relations in the phrase structure, and thus allows reconstructing the direct order of constituents, e.g.: the direct word order in impersonal sentence (9) can be transformed to the unprojective word order in (10):

(9) *Хлопця збирають в далеку дорогу* ($N_{acc.\mathbf{masc}}$ $V_{3p.pl.}$ $prep_{<Acc>\ NP}$[$Adj_{acc.\mathbf{fem}}$ $N_{acc.\mathbf{fem}}$])

$boy_{acc.sing.masc}$ $they.prepare_{pres.plur.p3}$ $in_{/acc}$ $long_{Adj.acc.sing.fem}$ $journey_{acc.sing.fem}$

They prepare a boy for a long journey

(10) *В далеку хлопця збирають дорогу* ($prep_{<Acc>\ NP}$[$Adj_{acc.\mathbf{fem}}$… $N_{acc.\mathbf{masc}}$ $V_{3p.pl.}$ …$N_{acc.\mathbf{fem}}$])

In (10) the syntactic link between an $Adj_{acc.fem}$ *(далеку)* and $N_{acc.fem}$ *(дорогу)* is preserved because of:

(a) a difference in gender feature with the noun which breaks the noun phrase: $N_{acc.masc}$ *(хлопця)*;

(b) a difference in semantic features between the nouns "*хлопець*" (a boy) and "*доро́га*" (a journey).

A similar transformation is less acceptable if the value of the gender feature is the same in both nouns, as in (11) ⇒ (12), though semantic features and intonation still allow reconstructing the direct word order:

(11) *Дівчину збирають в далеку дорогу* ($N_{acc.\mathbf{fem}}$ $V_{3p.pl.}$ $prep_{<Acc>\ NP}$[$Adj_{acc.\mathbf{fem}}$ $N_{acc.\mathbf{fem}}$])

$girl_{N.acc.sing.fem}$ $they.prepare_{V.pres.plur.p3}$ $in_{/acc}$ $long_{Adj.acc.sing.fem}$ $journey_{N.acc.sing.fem}$

They prepare a girl for a long journey

(12) ? *В далеку %*[2] *дівчину збирають дорогу* ($prep_{<Acc>\ NP}$[$Adj_{acc.\mathbf{fem}}$… $N_{acc.\mathbf{fem}}$ $V_{3p.pl.}$ …$N_{acc.\mathbf{fem}}$])

If even semantic features of both nouns are the same, then the sentence will be not acceptable for most of the speakers under the unprojective interpretation (the alternative "projective" interpretation, despite being awkward, will remain the only possible). The transformation (13) ⇒ (14) is hardly acceptable:

(13) *Валізу збирають в далеку дорогу* ($N_{acc.\mathbf{fem}}$ $V_{3p.pl.}$ $prep_{<Acc>\ NP}$[$Adj_{acc.\mathbf{fem}}$ $N_{acc.\mathbf{fem}}$])

$suitcase_{N.acc.sing.fem}$ $they.prepare_{V.pres.plur.p3}$ $in_{/acc}$ $long_{Adj.acc.sing.fem}$ $journey_{N.acc.sing.fem}$

They prepare a suitcase into a long journey

(14) ?? *В далеку % валізу збирають дорогу* ($prep_{<Acc>\ NP}$[$Adj_{acc.\mathbf{fem}}$… $N_{acc.\mathbf{fem}}$ $V_{3p.pl.}$ …$N_{acc.\mathbf{fem}}$])

$in_{/acc\ NP}$[$long_{Adj.acc.sing.fem}$ … $suitcase_{N.acc.sing.fem}$ $they.prepare_{V.pres.plur.p3}$ …$journey_{N.acc.sing.fem}$]

– the possible "projective" interpretation: 'They collect [pieces of] a road into a distant suitcase' (this sentence should be used without the phrase boundary).

There are some categorical constraints on unprojective permutations, e.g.:

(a) a preposition cannot be separated from at least one of the component of the following NP (an adjective or a noun) with an appropriate value of a case feature, and

(b) a preposition has to come before any constituent of its NP.

Sentences (15), (16) and (17) are derived from (1), but they violate these constraint, so they are categorically unacceptable:

(15) * *В збираюся далеку дорогу* ($_{PP}$[prep… V …Adj N]) – condition (a) is violated

(16) * *Далеку в дорогу збираюся* ($_{NP}$[Adj… prep …N] V) – condition (b) is violated

(17) * *Дорогу в збираюся далеку* ($_{NP}$[N… prep V …Adj]) – conditions (a) and (b) are violated

Unprojective sentences are grammatical, at least in a sense that they clearly differ from ungrammatical sentences 5-6, 15-17. But their acceptability is a non-categorical phenomenon, and their distribution differs from the distribution of projective sentences. Unprojective word order is always marked stylistically or emotionally and expresses the speaker's 'less restricted' state in voicing thoughts and feelings.

In modern Ukrainian unprojective sentences are used mainly in poetry, in spontaneous speech, and in the direct speech of characters in prosaic texts. However, in Old Ukrainian of 17th century, during a

[2] *%* – stands for a phrase boundary.

baroque period, it was a sign of a formal "high" written style. Probably, this feature can be attributed to a baroque "way of thinking", which was characterised by "joining of what could not be joined". E.g., the sentence (18) opens a chronicle written by a Cossack historian Samiylo Velychko about the events of the Ukrainian war for independence of 1648-1656 (led by Bohdan Khmelnytsky): (18)

Ним	*зачну*	NP[$_i$ *наступуючоє …*	NP[$_j$ *воєнних…*	*Хмелницкого*	*…діл* $_j$]	*з*	*Поляки*	*…поведеніє* $_i$]
by this	I.will start	following	military	of Khmelnytsky	actions	with	Poles	conduct
N.INS. SING	V.SING. 1st.FUT	A.ACC.SING.NEUT	A.GEN.PLUR	N.GEN.SING	N.GEN. PLUR		N.INS. PLUR	N.ACC SING.NEUT

'By this I will start [to relate] the following conduct of military actions by Khmelnytsky against Poles'.

The phrase "*the following conduct of military actions by Khmelnytsky*" has an unprojective word order with literal translation: "*following of military by Khmelnytsky actions conduct*" (a PP "*with Poles*" is a complement of the word "*actions*", like the genitive "*of Khmelnytsky*"). Morphological and semantic features allow the recipient finding appropriate syntactic links and reconstructing the direct word order with the corresponding isomorphic constituent structure, as in (19) and (20):

(19) *Ним зачну* NP[$_i$ *наступучюоє поведеніє* $_i$] NP[$_j$ *воєнних діл* $_j$] *Хмелницкого з Поляки*.

With.this$_{pron.ins.sing.masc}$ I.will.start$_{V.sing.1st.fut}$ following$_{Adj.acc.sing.neut}$ conduct$_{N.acc.sing.neut}$ military$_{Adj.gen.plur}$ actions$_{N.gen.plur.}$ Khmelnytsky$_{N.gen.sing.mask}$ with$_{Prep.inst}$ Poles$_{N.inst.plur}$

(20) VP[NP.inst[*Ним*$_{N.INST.SING}$]
V[*зачну*$_{V.SING.FUT.PERF}$]
NP.acc[NP.acc[*наступуючоє*$_{A.ACC.SING}$ *поведеніє*$_{N.ACC.SING}$]
NP.gen[NP.gen [*воєнних*$_{A.GEN.PLUR}$ *діл*$_{N.GEN.PLUR}$]
NP.gen [*Хмелницкого*$_{N.GEN.SING}$]
PP[*з Поляки*]]]]

It is clear that unprojective sentences require more complex parsing algorithms. A greater computational load on a recipient can explain their limited distribution.

Representation of word order variation phenomena. Different frameworks can be used for representing sentences with the described word order types, e.g., [Gladkiy, 1985], [Rambow, Lee, 1994], [Rambow, Joshi, 1994]. In this paper we use a constituency framework based on the annotation scheme developed for similar phenomena in German [Skut et al., 1997], [Brants, Skut, 1998]. The advantages of such scheme for representing word order variation in Slavic languages are:

(a) Synonymous sentences are always described by isomorphic constituency trees, i.e., which can be derived from each other by changing the order of brunches in subtrees [Sterling, Shapiro, 1986]. In other words, the trees of synonymous sentences share structural organisation, but differ in the linear order of brunches or leaves. If sentences differ only in their word order, then isomorphism of their constituent structure trees always implies synonymy of these sentences.

(b) Restrictions on word order variation are naturally described as restrictions on certain types of isomorphic transformations of trees.

(c) The information about the direct word order for each sentence is present in such trees; the direct word order can be reconstructed by isomorphic transformations of trees.

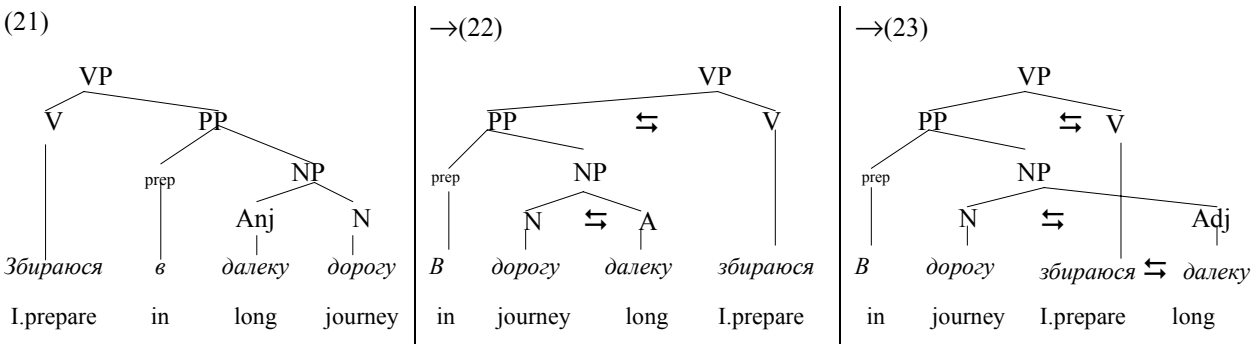
The use of this framework for representing *unprojective* phrases requires extending a standard definition of constituent structure trees [Partee et al., 1993: 437-444], as proposed in [Gladkiy, 1985: 37]. In particular, the trees need not obey the non-tangling condition: for a well-formed tree it is not required that if a node *x* precedes a node *y*, then all nodes dominated by *x* precede all nodes dominated by *y*. The removal of this condition allows brunches to cross in constituent structure trees, so constituents need not necessarily be continuous segments. Discontinuous constituents are created with a special kind of isomorphic tree transformation, where the leaves belonging to different subtrees can change their linear order, preserving their structural links.

In this framework, the sentence (1) with the direct word order will have the constituent structure tree (21). By changing order of brunches in subtrees, it can be transformed into the isomorphic tree (22), which represents the structure of the unconfigurational sentence (4). Further, by changing order of leaves from different subtrees, the "direct word order" tree (21) can be transformed into the isomorphic tree (23), which represents the structure of the unprojective sentence (8). Word order in sentences (1) (4) (8) can be viewed as derived in a chain (1) → (4) → (8), similar to the word formation chains.

(1) *Збираюся в далеку дорогу* (V [prep Adj N]$_{obj}$)

(4) *В дорогу далеку збираюся* ([prep [N ⇆Adj]] ⇆ V)

(8) *В дорогу збираюся далеку* (PP[prep N… V … ⇆Adj])



Modeling word order variation. The task of a model of word order variation is

(a) to reconstruct the direct word order (and a constituency system tree) for any sentence and

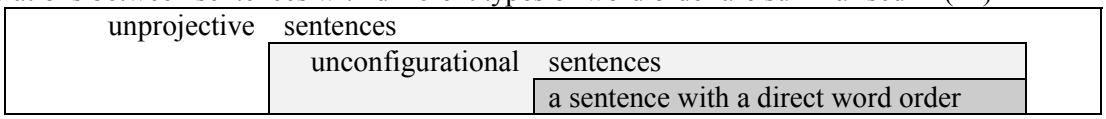
(b) to derive the complete set of synonymous sentences with different word order from the sentence with the direct word order. Depending on the type of word order variation, this task consists of

(b.1) deriving a set of *unconfigurational* sentences from the sentence with the direct word order

(b.2) deriving a set of possible *unprojective* sentences from each unconfigurational sentence created on the stage (b.1), and from the 'direct word order' sentence.

The relations between sentences with different types of word order are summarised in (24)

(24)



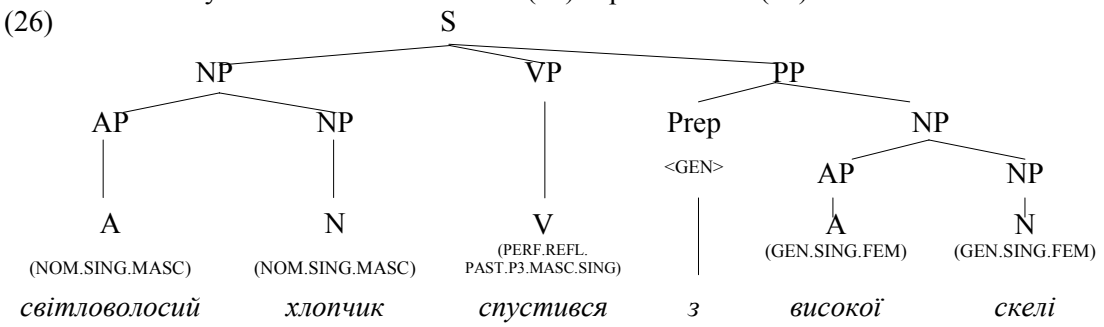
Further we show an example of (b) – generating a set of possible synonymous sentences with word order variation for the sentence (25) with the direct word order

(25)	*Світловолосий*$_1$	*хлопчик*$_2$	*спустився*$_3$	*з*$_4$	*високої*$_5$	*скелі*$_6$.
	fair-haired	boy	came down	from	high	rock
	ADJ (NOM.SING.MASC)	N (NOM.SING. MASC)	V (PERF.REFL. PAST.P3.MASC.SING)	PREP (<GEN>)	ADJ (GEN.SING.FEM)	N (GEN.SING. FEM)

'The fair-haired boy came down from the high rock'

The constituent system tree for the sentence (25) is presented in (26):

(26)



The equivalent bracket notation for the direct word order sentence (25) is presented in (28.1).

To derive the set of unconfigurational sentences for the sentence (25), we will systematically change the order of brunches in subtrees of the tree (26) (except the brunches of PP, which are not allowed to change their order, as discussed above). The set of unconfigurational sentences that is derived from the direct word order in (28.1) is presented in (28.1.1 – 28.6.3):

(28)

1.[S [NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] *спустився*$_{3.V}$ [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]].

1.1.[S [NP *хлопчик*$_{2.N}$ ⇆*світловолосий*$_{1.A}$] *спустився*$_{3.V}$ [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]].

1.2.[S [NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] *спустився*$_{3.V}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]]].

1.3.[S [NP *хлопчик*$_{2.N}$ ⇆ *світловолосий*$_{1.A}$] *спустився*$_{3.V}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆ *високої*$_{5.A}$]]].

2.[S [NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]] ⇆*спустився*$_{3.V}$].

2.1.[S [NP *хлопчик*$_{2.N}$ ⇆ *світловолосий*$_{1.A}$] [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]] ⇆*спустився*$_{3.V}$].

2.2.[S [NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆ *високої*$_{5.A}$]] ⇆*спустився*$_{3.V}$].

2.3.[S [NP *хлопчик*$_{2.N}$ ⇆ *світловолосий*$_{1.A}$][PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆ *високої*$_{5.A}$]] ⇆*спустився*$_{3.V}$].

3.[S *спустився*$_{3.V}$ ⇆ [NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]].
3.1.[S *спустився*$_{3.V}$ ⇆ [NP *хлопчик*$_{2.N}$ ⇆*світловолосий*$_{1.A}$] [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]].
3.2.[S *спустився*$_{3.V}$ ⇆ [NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]]].
3.3.[S *спустився*$_{3.V}$ ⇆ [NP *хлопчик*$_{2.N}$ ⇆*світловолосий*$_{1.A}$] [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]]].

4.[S *спустився*$_{3.V}$ [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]] ⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$]].
4.1.[S *спустився*$_{3.V}$ [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]] ⇆[NP *хлопчик*$_{2.N}$ ⇆*світловолосий*$_{1.A}$]].
4.2.[S *спустився*$_{3.V}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆ *високої*$_{5.A}$]] ⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$]].
4.3.[S *спустився*$_{3.V}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]] ⇆[NP *хлопчик*$_{2.N}$ ⇆*світловолосий*$_{1.A}$]].

5.[S [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] *спустився*$_{3.V}$].
5.1.[S [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]⇆[NP *хлопчик*$_{2.N}$ ⇆ *світловолосий*$_{1.A}$] *спустився*$_{3.V}$].
5.2.[S [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]]⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] *спустився*$_{3.V}$].
5.3.[S [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]]⇆[NP *хлопчик*$_{2.N}$ ⇆ *світловолосий*$_{1.A}$] *спустився*$_{3.V}$].

6.[S [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]⇆*спустився*$_{3.V}$⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$]].
6.1.[S [PP *з*$_{4.prep}$ [NP *високої*$_{5.A}$ *скелі*$_{6.N}$]]⇆*спустився*$_{3.V}$⇆[NP *хлопчик*$_{2.N}$ ⇆*світловолосий*$_{1.A}$]].
6.2.[S [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]]⇆*спустився*$_{3.V}$⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$]].
6.3.[S [PP *зі*$_{4.prep}$[NP *скелі*$_{6.N}$ ⇆*високої*$_{5.A}$]]⇆*спустився*$_{3.V}$⇆[NP *хлопчик*$_{2.N}$ ⇆*світловолосий*$_{1.A}$]].

Each of the sentences in (28) can be the basis for a set of sentences with *unprojective* word order, each of which can have different degree of acceptability. The rules that relate the unprojective phrase structure to degree of acceptability of such sentences are not yet clearly established. As an example, we present a set of acceptable unprojective sentences derived from the sentence (28.4.2):
28.4.2.[S *спустився*$_{3.V}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$⇆ *високої*$_{5.A}$]] ⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$]].
.1.[S [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$⇆… *спустився*$_{3.V\ ...}$ *високої*$_{5.A}$]] ⇆[NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$]].
.2.[S [NP *світловолосий*$_{1.N...}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$⇆… *спустився*$_{3.V\ ...}$ *високої*$_{5.A}$]] …*хлопчик*$_{2.N}$]].

.3.[S [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$⇆ *високої*$_{5.A}$]] ⇆[NP *світловолосий*$_{1.A\ ...}$ *спустився*$_{3.V\ ...}$ *хлопчик*$_{2.N}$]].
.4.[S [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$⇆… [NP *світловолосий*$_{1.A\ ...}$ *спустився*$_{3.V\ ...}$ *хлопчик*$_{2.N}$] … *високої*$_{5.A}$]]].

.5.[S *спустився*$_{3.V}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$⇆… [NP *світловолосий*$_{1.A}$ *хлопчик*$_{2.N}$] $_{...}$ *високої*$_{5.A}$]]].
.6.[S *спустився*$_{3.V}$ ⇆[NP *світловолосий*$_{1.A...}$ [PP *зі*$_{4.prep}$ [NP *скелі*$_{6.N}$⇆ *високої*$_{5.A}$]]… *хлопчик*$_{2.N}$]].

Unprojective sentences in modern Ukrainian are stylistically distinct from sentences with the two other types of word order. Native speakers feel stylistic 'unrestrictedness' of sentences with the unprojective word order, the 'peripheral' character of these sentences, which nevertheless remain grammatical and are widely accepted in 'unrestricted' styles of Ukrainian, such as poetry. E.g. in the line taken from the poem of the modern Ukrainian poet Vasyl' Stus, presented in (29), the noun phrase *глупа ніч* '*the late night*' becomes discontinuous because its constituents are separated by the verb:

(29)

І	[$_{i}$***глупа***..	*облягає…*	***ніч*** $_{i}$**]**	*пекельний*	*край*	*і*	*крик*	*пекельний*
and	late	surrounds	night	infernal	land	and	cry	infernal
	A.NOM. SING.FEM	V.3rd.SING. PRES	N.NOM. SING.FEM	A.ACC.SING. MASC	N.ACC SING.MASC		N.ACC. SING.MASC	A.ACC. SING.MASC

'And the late night surrounds the infernal land and the infernal cry'

In this paper we do not discuss the problem of finding exact complexity of the parsing algorithm for unprojective sentences, or the problem of finding all constraints which govern their generation. We note, however, that unprojective word order requires more complex parsing and generation algorithms than that is required by context-free languages. At the same time, declarative sentences with the direct and unconfigurational word order can be analysed as context-free. From this point of view, the limited distribution of unprojective sentences correlates with their greater processing complexity.

Further we examine a problem of restrictions on centre embedding in Ukrainian, in the developed framework of word order variation. In particular, unconfigurational word order variation allows building construction of different types and of different levels of embedding, so their acceptability and comprehensiveness can be examined.

Restrictions on centre embedding. Centre-embedded constructions, such as the relative clause in the sentence (30):

(30) *The rat the cat bit ate the cheese.*

– present a challenging problem for linguists and psychologists: certain types of such constructions allow multiply levels of centre-embedding, while many types of relative clauses can be embedded only once, e.g., in (30) only one level of centre embedding is allowed, and parsing such sentences is difficult [Miller, Chomsky, 1963], [Abney, Johnson, 1991: 233]:

(31) * *The rat the cat the dog chased bit ate the cheese.*

Alternatively, the sentence (32) (with two levels of embedding) is acceptable, according to [Levis, 1997: 4], though in general constructs with central embedding are hard to process [Hawkins, 1999: 252].

(32) *That the food that John ordered tasted good pleased him.*

Different accounts for explaining such phenomena have been proposed (an overview can be found in [Levis, 1997: 5-12]).

Further we present examples of Ukrainian constructions that allow up to 3 or 4 levels of centre embedding. Comprehensiveness of these sentences is changed gradually. Such constructions are related to synonymous phrases without embedding and can be derived from them by isomorphic *unconfigurational* transformations in the phrase structure. This proves grammaticality of such constructions, and agrees with measurements of the size of human short-term memory [Yngve, 1961] (which, according to Victor Yngve, equals to 7±2 units – we assume that one level of embedding requires 2 memory units to be parsed). On the other hand, incomprehensible sentences with 2 levels of embedding of relative clauses can be shown to violate feature coherence, so the difficulties to parse these sentences appear on the structural level and are not related to the depth of embedding.

Ukrainian exposes a great degree of tolerance for centrally embedded structures. Constructs with centre embedding in Ukrainian could be easily transformed into constructs with embedding on the right side and vice versa by unconfigurational permutation of constituents. In (33) the examples of synonymous phrases with the centre embedding (33a) and without it (33b) are presented:

(33a) $_{NP}[_{AP}[_{A}$ *відомий* $_{PP}[$*у західних країнах*$]]$ $_{N}$ *письменник*$]$

$\text{known}_{\text{A.NOM.SING}}$ in_{PREP} $\text{western}_{\text{A.LOC.PLUR}}$ $\text{countries}_{\text{N.LOC.PLUR}}$ $\text{writer}_{\text{N.NOM.SING}}$

⇔ (33b) $_{NP}[_{N}$ *письменник*, ⇆ $_{AP}[_{A}$ *відомий* $_{PP}[$*у західних країнах*$]]]$

$\text{writer}_{\text{N.NOM.SING}}$ $\text{known}_{\text{A.NOM.SING}}$ in_{PREP} $\text{western}_{\text{A.LOC.PLUR}}$ $\text{countries}_{\text{N.LOC.PLUR}}$

'A writer, known in western countries'

The recursive centre embedding is usually possible in Ukrainian. In the examples of the recursive centre embedding we will indicate the maximum level of centre embedding, as described in [Gladkiy, 1985]. The higher is the maximum level of centre embedding, the more cumbersome and the more difficult to process is the construct. In written form much more complicated constructs still remain understandable, but when uttered orally, they may be considered by native speakers totally incomprehensible. The more complicated is the construct, the smaller number of informants will accept it, so in general it is difficult to state a certain number of centre embedding levels, allowed in Ukrainian. In any case, these judgements will always remain non-categorical. In (34) several synonymous pairs of constructs are presented with and without centre embedding. The construct without centre embedding in example (a) is considered well formed and comprehensible, further examples cause more and more speakers' rejections in oral and then also in written speech[3]:

(34) (a) $_{NP}[_{6AP}[_{5}$ *отримана*

$_{PP}[_{4}$*від* $_{NP}[_{3}$ $_{AP}[_{2}$*відомого*

$_{PP}[_{1}$*у західних країнах*$_{1}]_{2}]$

письменника$_{3}]_{4}]_{5}]$

книга$_{6}]$ **(2)**

$\text{received}_{\text{A.NOM.SING.FEM}}$ $\text{from}_{\text{PREP}}$ $\text{known}_{\text{A.NOM.GEN.MASC}}$ in_{PREP} $\text{western}_{\text{A.LOC.PLUR.FEM}}$ $\text{countries}_{\text{N.LOC.PLUR.FEM}}$ $\text{writer}_{\text{N.GEN.SING.MASC}}$ $\text{book}_{\text{N.NOM.SING.FEM}}$

[3] We indicate the level of embedding in brackets and provide the synonymous sentence without centre embedding (the level of embedding is 0) next to the sentence with the embedding.

⇔ (a') $_{NP}[_{N}$ *книга,*

↓↑

$_{AP}[$*отримана від* $_{NP}[_{N}$ *письменника,*

↓↑

$_{AP}[$*відомого у західних країнах]]]]* **(0)**

book$_{N.NOM.SING.FEM}$ received$_{A.NOM.SING.FEM}$ from$_{PREP}$ writer$_{N.GEN.SING.MASC}$ known$_{A.NOM.GEN.MASC}$ in$_{PREP}$ western$_{A.LOC.PLUR.FEM}$ countries$_{N.LOC.PLUR.FEM}$

'A book, which was received from the writer, who is known in western countries'

(b) $_{NP}[_{9AP}[_{8}$*характеризований*

$_{PP}[_{7}$*в* $_{NP}[_{6AP}[_{5}$ *отриманій*

$_{PP}[_{4}$*від* $_{NP}[_{3\ AP}[_{2}$*відомого*

$_{PP}[_{1}$*у західних країнах*$_{1}]_{2}]$

письменника$_{3}]_{4}]_{5}]$

книзі$_{6}]_{7}]$

персонаж$_{8}]_{9}]$ **(3)**

characterized$_{A.NOM.SING.MASC}$ in$_{PREP}$ received$_{A.LOC.SING.FEM}$ from$_{PREP}$ known$_{A.NOM.GEN.MASC}$ in$_{PREP}$ western$_{A.LOC.PLUR.FEM}$ countries$_{N.LOC.PLUR.FEM}$ writer$_{N.GEN.SING.MASC}$ book$_{N.LOC.SING.FEM}$ personage$_{N.NOM.SING.MASC}$

⇔ (b') $_{NP}[_{N}$ *персонаж,*

↓↑

$_{AP}[$*характеризований* $_{PP}[$*в* $_{NP}[_{N}$*книзі,*

↓↑

$_{AP}[$*отриманій від* $_{NP}[_{N}$ *письменника,*

↓↑

$_{AP}$ *[відомого у західних країнах]* **(0)**

personage$_{N.NOM.SING.MASC}$ characterized$_{A.NOM.SING.MASC}$ in$_{PREP}$ book$_{N.LOC.SING.FEM}$ received$_{A.LOC.SING.FEM}$ from$_{PREP}$ writer$_{N.GEN.SING.MASC}$ known$_{A.NOM.GEN.MASC}$ in$_{PREP}$ western$_{A.LOC.PLUR.FEM}$ countries$_{N.LOC.PLUR.FEM}$

'A personage, who is characterized in a book, which was received from the writer, who is known in western countries'

(c) $_{NP}[_{12AP}[_{11}$*пов'язана*

$_{PP}[_{10}$*з* $_{NP}[_{9AP}[_{8}$ *характеризованим*

$_{PP}[_{7}$*в* $_{NP}[_{6AP}[_{5}$ *отриманій*

$_{PP}[_{4}$*від* $_{NP}[_{3\ AP}[_{2}$*відомого*

$_{PP}[_{1}$*у західних країнах*$_{1}]_{2}]$

письменника$_{3}]_{4}]_{5}]$

книзі$_{6}]_{7}]$

персонажем$_{8}]_{9}]_{10}]_{11}]$

проблематика$_{12}]$ **(4)**

related$_{A.NOM.SING.FEM}$ to$_{PREP}$ characterized$_{A.INS.SING.MASC}$ in$_{PREP}$ received$_{A.LOC.SING.FEM}$ from$_{PREP}$ known$_{A.NOM.GEN.MASC}$ in$_{PREP}$ western$_{A.LOC.PLUR.FEM}$ countries$_{N.LOC.PLUR.FEM}$ writer$_{N.GEN.SING.MASC}$ book$_{N.LOC.SING.FEM}$ personage$_{N.INS.SING.MASC}$ problems$_{N.NOM.SING.FEM}$

⇔ (c') $_{NP}[_{N}$ *проблематика,*

↓↑

$_{AP}[$*пов'язана з* $_{NP}[_{N}$ *персонажем,*

↓↑

$_{AP}[$*характеризованим в* $_{NP}[_{N}$ *книзі,*

↓↑

$_{AP}[$*отриманій від* $_{NP}[_{N}$ *письменника,*

↓↑

$_{AP}[$*відомого у західних країнах]]]]]]]* **(0)**

problems$_{N.NOM.SING.FEM}$ related$_{A.NOM.SING.FEM}$ to$_{PREP}$ personage$_{N.INS.SING.MASC}$ characterized$_{A.INS.SING.MASC}$ in$_{PREP}$ book$_{N.LOC.SING.FEM}$ received$_{A.LOC.SING.FEM}$ from$_{PREP}$ writer$_{N.GEN.SING.MASC}$ known$_{A.NOM.GEN.MASC}$ in$_{PREP}$ western$_{A.LOC.PLUR.FEM}$ countries$_{N.LOC.PLUR.FEM}$

'Problems, that are related to a personage, who is characterized in a book, which was received from the writer, who is known in western countries'

⇔ (d) $_{NP}[_{15AP}[_{14}$*представлена*
$_{PP}[_{13}$*у* $_{NP}[_{12AP}[_{11}$*пов'язаній*
$_{PP}[_{10}$*з*$_{NP}[_{9AP}[_{8}$ *характеризованим*
$_{PP}[_{7}$*в* $_{NP}[_{6AP}[_{5}$ *отриманій*
$_{PP}[_{4}$*від* $_{NP}[_{3\ AP}[_{2}$*відомого*
$_{PP}[_{1}$*у західних країнах*$_{1}]_{2}]$
письменника$_{3}]_{4}]_{5}]$
книзі$_{6}]_{7}]$
персонажем$_{8}]_{9}]_{10}]_{11}]$
проблематиці$_{12}]_{13}]_{14}]$
концепція$_{15}]$ **(5)**

represented$_{A.NOM.SING.FEM}$ in$_{PREP}$ related$_{A.LOC.SING.FEM}$ to$_{PREP}$ characterized$_{A.INS.SING.MASC}$ in$_{PREP}$ received$_{A.LOC.SING.FEM}$ from$_{PREP}$ known$_{A.NOM.GEN.MASC}$ in$_{PREP}$ western$_{A.LOC.PLUR.FEM}$ countries$_{N.LOC.PLUR.FEM}$ writer$_{N.GEN.SING.MASC}$ book$_{N.LOC.SING.FEM}$ personage$_{N.INS.SING.MASC}$ problems$_{N.LOC.SING.FEM}$ conception$_{N.NOM.SING.FEM}$

(d') $_{NP}[_{N}$*концепція,*
↓↑
$_{AP}$*[представлена у* $_{NP}[_{N}$*проблематиці,*
↓↑
$_{AP}$*[пов'язаній з* $_{NP}[_{N}$*персонажем,*
↓↑
$_{AP}$*[характеризованим в* $_{NP}[_{N}$*книзі,*
↓↑
$_{AP}$*[отриманій від* $_{NP}[_{N}$*письменника,*
↓↑
$_{AP}$*[відомого у західних країнах]]]]]]]]]* **(0)**

conception$_{N.NOM.SING.FEM}$ represented$_{A.NOM.SING.FEM}$ in$_{PREP}$ problems$_{N.LOC.SING.FEM}$ related$_{A.LOC.SING.FEM}$ to$_{PREP}$ personage$_{N.INS.SING.MASC}$ characterized$_{A.INS.SING.MASC}$ in$_{PREP}$ book$_{N.LOC.SING.FEM}$ received$_{A.LOC.SING.FEM}$ from$_{PREP}$ writer$_{N.GEN.SING.MASC}$ known$_{A.NOM.GEN.MASC}$ in$_{PREP}$ western$_{A.LOC.PLUR.FEM}$ countries$_{N.LOC.PLUR.FEM}$

'A conception, which is represented in problems, that are related to a personage, who is characterized in a book, which was received from the writer, who is known in western countries'

The sentence (34c), which has the maximum level of embedding "4" still could be acceptable in written form, but (34d) with level "5" already could hardly be comprehensible even in a written text in Ukrainian. From the examples presented above it could be concluded that the constructions with recursive centre embedding with maximum levels of embedding from "1" to "3" are grammatical and comprehensible in Ukrainian, and even the higher level of centre embedding – "4" – is possible under certain circumstances.

However, in Ukrainian there are constructs, similar to the unacceptable English sentence (31), where multiple levels of centre embedding become abruptly incomprehensible (starting from the level 2). These are also sentences with certain types of embedded relative clauses, as in English. E.g., in the sentence (35) the level of centre embedding is "1", so it is the acceptable sentence in Ukrainian, but the sentence (36) is not: its level of centre embedding is "2". Sentences with higher levels of centre embedding are unacceptable either:

(35) $[_{S}$ $[_{NP:subj}$ *Дівчина,* $[_{S}$ *яку пісня чарувала],* $_{V:pred}$ *раділа].*

girl$_{N.NOM.SING.FEM}$ whom$_{PRON.ACC.SING.FEM}$ song$_{N.NOM.SING.FEM}$ fascinated$_{V.SING.FEM.PAST.IMPERF}$ rejoiced$_{V.SING.FEM.PAST.IMPERF}$

'A girl, who was fascinated by the song, was rejoicing'

(36) * $[_{S}$ $[_{NP:subj}$ *Дівчина,*
$[_{S}$*яку* $[_{NP:subj}$ *пісня,*
$[_{S}$*яку пташка вела]],*
$_{V:pred}$ *чарувала]],*
$_{V:pred}$ *раділа].*

girl$_{N.NOM.SING.FEM}$ whom$_{PRON.ACC.SING.FEM}$ song$_{N.NOM.SING.FEM}$ which$_{PRON.ACC.SING.FEM}$ bird$_{N.NOM.SING.FEM}$ sang$_{V.SING.FEM.PAST.IMPERF}$ fascinated$_{V.SING.FEM.PAST.IMPERF}$ rejoiced$_{V.SING.FEM.PAST.IMPERF}$

'A girl, who was fascinated by the song sung by the bird, was rejoicing'

– this proposition in Ukrainian could be expressed by the means of subordinate clauses without centre embedding, e.g. with right embedding of the object subordinate clauses, as (37), or at least with the level of centre embedding "1", as (38).

(37) *[$_S$Пташка вела [$_{NP:obj}$ пісню, [$_S$яка чарувала[$_{NP:obj}$ дівчину, [$_S$яка раділа]]]]]*

bird$_{N.NOM.SING.FEM}$ sang$_{V.SING.FEM.PAST.IMPERF}$ song$_{N.NOM.SING.FEM}$ which$_{PRON.\mathbf{NOM}.SING.FEM}$ fascinated$_{V.SING.FEM.PAST.IMPERF}$ girl$_{N.\mathbf{ACC}.SING.FEM}$ who$_{PRON.\mathbf{NOM}.SING.FEM}$ rejoiced$_{V.SING.FEM.PAST.IMPERF}$

'A bird sang a song which fascinated a girl who was rejoicing'

(38)*[$_S$[$_{NP:subj}$ Дівчина, [$_S$яку чарувала [$_{NP:obj}$ пісня, [$_S$яку вела пташка]]]], $_V$ раділа]*

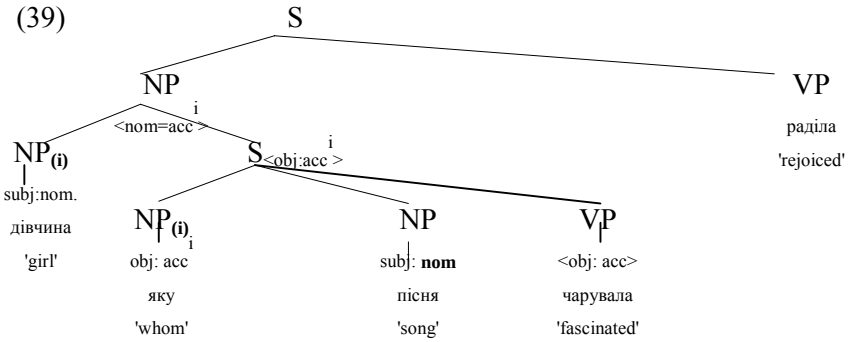
girl$_{N.NOM.SING.FEM}$ whom$_{PRON.ACC.SING.FEM}$ fascinated$_{V.SING.FEM.PAST.IMPERF}$ song$_{N.NOM.SING.FEM}$ which$_{PRON.ACC.SING.FEM}$ sang$_{V.SING.FEM.PAST.IMPERF}$ bird$_{N.NOM.SING.FEM}$ rejoiced$_{V.SING.FEM.PAST.IMPERF}$

'A girl, who was fascinated by the song, which the bird sang, was rejoicing'

It is not possible to fully explain the abrupt change in comprehensiveness of the embedded object relative clauses by limits on human capacity to hold too many incomplete substructures (as it was suggested in [Miller, Chomsky, 1963], [Abney, Johnson, 1991]), so this phenomenon requires a more complex explanation. One of the possible accounts for this problem is presented in [Levis, 1997]. In this paper we show that rich feature structures, which are explicitly present in Slavic morphology, allow explaining the facts of comprehensiveness distortion by feature inconsistencies in the phrase structure of such sentences.

First we examine the acceptable sentence (35). Its phrase structure with case features and indices of co-referential phrases is presented in (39):

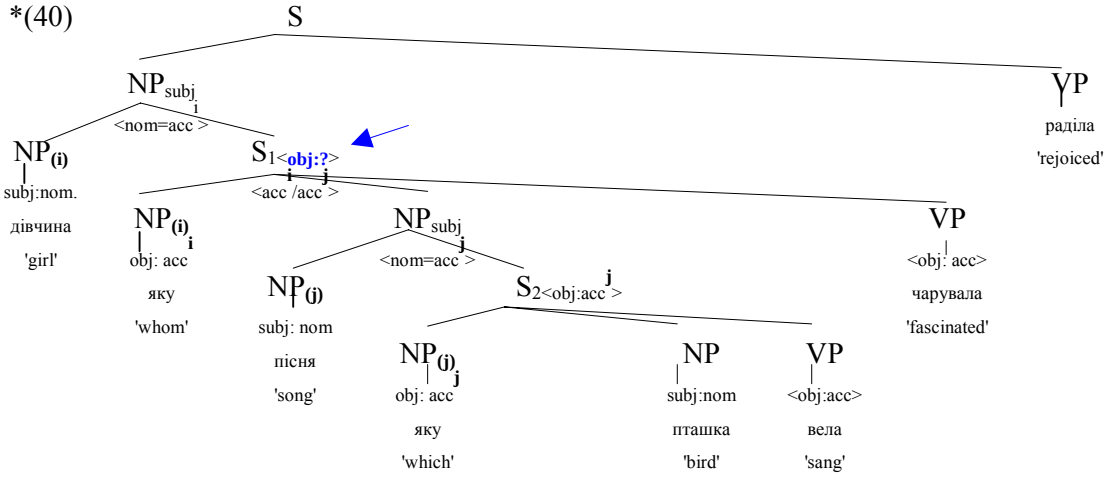
(39)



The pronoun *яку* – 'whom$_{acc.sing.fem}$' (the object of the embedded clause) is co-referential with the subject of the main clause: *дівчина* – 'girl$_{nom.sing.fem}$', which is indicated by indices "$_{(i)}$". Co-referential relations between the noun in nominative and the pronoun in accusative are also indicated by "$_{<nom=acc>}^{i}$" at the level of the parent NP of the subject in the main clause. We suggest that at the time, when the verb is processed, the accusative object of the verb must be also identified in the sentence. This is indicated in (39) on the level S of the subordinate clause by "$_{obj:acc}^{i}$".

But in (36) it is not possible to identify the accusative object in the first embedded subordinate clause in a similar way: the case features in the second subordinate clause prevent this. As a result the sentence (36) becomes incomprehensible. The phrase structure of (36) is presented in (40):

*(40)



On the level of the second embedded subordinate clause S_2 the identification of the accusative object "$_{obj:acc}^{j}$" is successful, like in (39). But we suggest that on the level of the first embedded clause S_1 the accusative object required by the verb "$_{чарувала}$" ('$_{fascinated}$') cannot be identified, because the

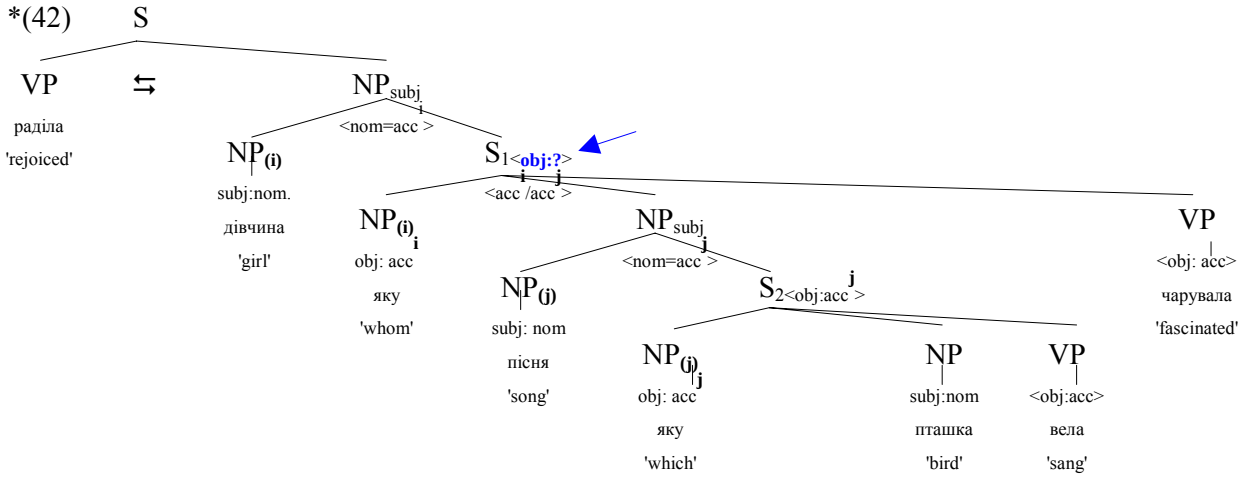
"accusative" case feature is already present in both sister nodes of the verb: in the subject $NP_{subj<nom=acc>}^{j}$ and in the pronoun object $NP_{(i)}$ obj: acc ^{i} яку 'whom'. As a result, the recipient cannot answer the question 'who was fascinated?' – 'the song' or 'the girl' because of inconsistency in feature structures on the top level of the first embedded subordinate clause: $S_{1<obj:?>}$. This explains why the two levels of embedding of subordinate clauses become incomprehensible (particularly – for case when the clauses modify subjects in a higher level clause, and this subject is co-referential with an object pronoun inside such subordinate clause).

In addition, the proposed explanation suggests that embedding in the main clause in (40) does not influence intelligibility of this sentence. In other words, we can change the order of the subject and verb in the main clause: "Subj. V" into "V ⇆ Subj" (as it is allowed by isomorphic unconfigurational transformation of 40), so the level of embedding will be 1, but the sentence will remain incomprehensible. This prediction is correct. Indeed, the sentence (41) (its phrase structure is shown in 42) – with 2 relative clauses and only 1 level of embedding – remains incomprehensible:

(41) *[$_S$ *Раділа*$_{V:pred}$ ⇆ *дівчина*$_{N:subj}$, [$_S$ *яку*$_{Pron:obj}$ *пісня*$_{N:subj}$, [$_S$ *яку пташка вела], чарувала*$_{V:pred}$]].

rejoiced$_{V.SING.FEM.PAST.IMPERF}$ girl$_{N.NOM.SING.FEM}$ whom$_{PRON.ACC.SING.FEM}$ song$_{N.NOM.SING.FEM}$ which$_{PRON.ACC.SING.FEM}$ bird$_{N.NOM.SING.FEM}$ sang$_{V.SING.FEM.PAST.IMPERF}$ fascinated$_{V.SING.FEM.PAST.IMPERF}$

*(42)



The English sentence (43) (that is derived from 31) with the phrase structure similar to (42) and with only 1 level of embedding is also incomprehensible for the majority of the speakers:

(43) * *The cheese was eaten by the rat [the cat [the dog chased] bit].*

This proves that comprehensiveness of this type of sentences depends on the feature coherence in the phrase structure and is not directly related to the level of embedding and the recipient's short-term memory size.

Conclusions. 1. Computational complexity of different word order types in Ukrainian correlates with their stylistic distribution: direct and unconfigurational, which have the complexity of context-free languages, are stylistically neutral and used in all styles. Unprojective sentences, which are computationally more complex, are used mainly in spontaneous speech, in poetry and in the direct speech of characters in prose. Acceptability of unprojective sentences varies, and the judgements of native speakers about such acceptability are non-categorical. However, unprojective sentences clearly differ from ungrammatical sentences that are categorically unacceptable.

2. Comprehensiveness of centre-embedded constructs agrees with V.Yngve's depth hypothesis about the size of human short-term memory: up to 3 (or sometimes 4) levels of centre embedding are allowed, while a construct remains comprehensible. The existence of incomprehensible sentences with 1 and 2 levels of centre embedding can be explained by inconsistencies in phrase structure of such sentences, namely by incoherent feature structures.

The proposed account of word order variation can be used in the development of accurate parsers for Slavic languages.

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