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NUMERALS AND NUMBERS

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1. INTRODUCTION

Cardinals have two main uses: as cardinality predicates or modifiers and as number words:

(1) a. The apostles were **twelve** in number. predicate
b. What are the **eight** planets of the Solar system? modifier

(2) a. **Two** and **two** makes **four**. number words
b. **Eight** is the third power of **two**.

The predicate use is cross-linguistically restricted: it is not available, for instance, in Irish or Scottish Gaelic (Acquaviva 2008:189fn.) or in Russian:
The opposite can also be true: in some languages cardinals cannot be modifiers, see below

(3) a. Apostolov bylo/*byli dvenadcat'. Russian
apostles.GEN was.N.SG/were twelve
Apostles were twelve. (lit. 'Of (the) apostles there was twelve')

b. *Apostoly byli dvenadcat'.
apostles.NOM were twelve

Hypothesis to be defended:

The use of cardinals as number words is secondary and derived from their linguistic use

Evidence (cf. Ionin and Matushansky 2006, 2018):
- the nominal status of number words
- the construction of complex cardinals as a syntactic operation

Further support from psychology

2. THE SYNTACTIC COMPLEXITY OF COMPLEX CARDINALS

Ionin and Matushansky 2018: complex cardinals are constructed in syntax

Evidence that we have is threefold:
- Multiplication has the syntax of sisterhood: no intervening elements
- Addition has a different syntax involving coordinators and prepositions
- There are other operations that are all encoded by **regular syntactic means**

The internal syntax of complex cardinals is normal syntax

2.1. The syntax of multiplication

Cross-linguistically observed patterns are those of **modification or complementation**

Juxtaposition, no overt marking (English, German, French, etc., but also Persian – Mahootian 1997, Mace 2003, Perry 2005; Lezgian – Haspelmath 1993, Mano – Khachaturyan 2015, Maori – Bauer 2003, Mixtec – Macaulay 1996, etc.):

(4) one hundred million people

Agreement with the higher cardinal:

(5) a. b-ùdì **mà-wúmɔ̀ má-báá** Gyeli, Grimm 2015:196
2-person$_{1/2}$ 6-ten$_{5/6}$ 6-two
'20 people'

b. două sute Romanian, Dobrovie-Sorin and Giurgea 2013:137
two.F hundred$_F$
'two hundred'

Genitive or partitive case (e.g., Slavic, Finno-Ugric) or preposition (e.g., Romanian):

(6) a. kaksi.kymmentä. yksi. tuhatta Finnish, Karttunen 2006
two ten.PART one thousand.PART
'twenty-one thousand'

b. cin.zeci de mii de oameni Romanian, Corver 2001
fif.ty of thousands of men
'fifty thousand people'

Construct state:

(7) ʔarbaʕ-u miʔat-i ʔalf-i rajul-in Arabic
four-NOM.CS hundred.PL-GEN.CS thousand-GEN.CS man-GEN
'four hundred thousand men'

Not all cardinals behave the same (more on this below), but the patterns are systematic

2.2. The syntax of addition

Juxtaposition is frequent, but other **complementation strategies are unattested** and various means of indicating the formation of a complex or plural entity are used (see Hanke 2010 for less common strategies than):

(8) **coordination**

a. šlošim ve- šaloš Hebrew
thirty and three
thirty three

b. ʔarbaʕ-at-u ʔaalaaf-in wa- xams-at-u rijaal-in
four-FSG-NOM thousand.PL-GEN and five-FSG-NOM man.PL-GEN
'four thousand and five men' Arabic, Zabbal 2005

c. khe pɟhe-da ˈɲiː
twenty half-and two
'thirty' Dzongkha, Mazaudon 2007 (see also van Driem 1992:151)

(9) **locative preposition**: Biblical Welsh *ar* 'on'

a. un ar ddeg Biblical Welsh, Hurford 1975:163-164
one on ten
'eleven'

b. pedwar ar bymtheg
four on fifteen
'nineteen'

c. naw ar hugain
nine on twenty
'twenty-nine'

(10) **comitative preposition**: Tamashek (Tuareg of Mali) *ə̀d* 'with'

a. mærɑ́w médd-æn ə̀d sæmmos — Heath 2005:251-252
ten.M man-MPL with five
'fifteen men'

b. mærɑw-æ̀t ḍeḍ-en ə̀d sæmmós-æt
ten-F woman-FPL with five-FPL
'fifteen women'

(11) **case-marking** or other change of the higher conjunct: Telugu (Siromoney 1968)

a. reNDu.wandal.u — Krishnamurti and Gwynn 1985:108
two.hundred.NOM
'two hundred'

b. reNDu.wandal.a yaabhay okaTi
two.hundred.OBL fifty.NOM one.NOM
'two hundred fifty one'

c. nuur.u
hundred.NOM
'one hundred'

d. nuuT.a lraway okaTi
hundred.OBL twenty.NOM one.NOM
'one hundred twety one'

In addition (pun intended), subtractive strategies are also used:

(12) **locative preposition**: Latin *de* 'from'

un. de. viginti
one from twenty
'nineteen'

(13) **caritative preposition**: Romani *bi* 'without'

a. deš bi-jekh — Welsh Romani, Elšik and Matras 2006:167
ten without-one
'nine'

b. bi-trin-engiro trianda — Russian Romani, Elšik and Matras 2006:167
without-three-GEN thirty
'twenty seven'

(14) **overcounting**:

a. II menn hins ellifta tigar — Old Norse, Menninger 1969
two men in eleventh ten
'one hundred and two men'

b. metsy ma.ben trok — Chungli Ao, Clark 1893:45
twenty NEG.brought six
'sixteen'

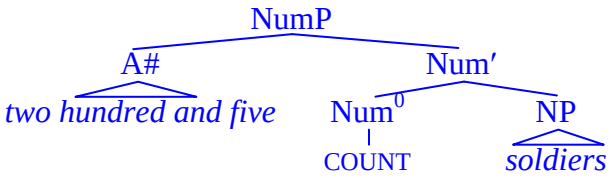
c. mükyi müpen tērŏk — Ao Mongsen, Mills 1926:343 (see also Coupe 2012)
twenty not.reached six
'sixteen'

The linguistic strategies employed for addition argue against a separate linguistic system for the construction of complex cardinals

3. AGAINST A SEPARATE COGNITIVE SYSTEM

The standard take on NP-internal cardinals treats them to the exclusion of the lexical NP (see Zabbal 2005, Wągiel 2018, among others, for a theory with the n-denotation of cardinals):

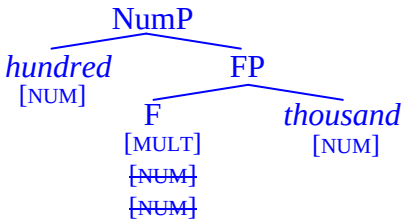
(15) Zabbal 2005



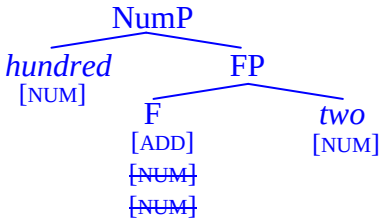
A complex cardinal is then constructed as a unit. How?

Di Sciullo 2015, 2017:

(16) a. multiplication



b. addition



Implicit: the numerals here denote numbers rather than cardinality predicates

What is expected from the semantics and syntax of F?

- F should perform the relevant arithmetic operation
- all arithmetic operators should have the same syntax or randomly show properties of modification, coordination and complementation
- all numbers formed by the same operation should have the same internal syntax

The reality is very different

3.1. Variant syntax within complex cardinals

Multiplicative **case-assignment**: the Russian cardinals 'two', 'three' and 'four' assign paucal case, whereas 'five' and higher assign genitive case:

(17) a. Russian
četyre tysjači šagov
four thousand.PAUC step.PL.GEN
'four thousand steps'

b.
pjat' tysjač šagov
five thousand.PL.GEN step.PL.GEN
'five thousand steps'

Potential solution (cf. Zabbal 2005): the mediating head assigns the case determined by its specifier

Explanation still needed: why is the lexical NP in (17a) not assigned paucal?

Biblical Welsh addition: besides being null (arguably, in the morphological juxtaposition in (18b)), $F_{[ADD]}$ can be **locative or coordinative in function of the higher addend**:

(18) a. cant a phedwar — Biblical Welsh, Hurford 1975
hundred **and** four
'one hundred and four'

b. pedwar ar bym.theg
four **on** fif.teen
'nineteen'

c. tri ar ddeg a thri ugain a deu-cant
three on ten and three twenty and two-hundred
'two hundred and seventy three'

Note the reversed order, excluding the same analysis as above

Russian **approximative inversion** distinguishes bare multiplication from bare addition

The phenomenon (Mel'čuk 1985, Fowler 1987, Franks 1994, 1995, Billings 1995, Isakadze 1998, Yadroff and Billings 1998, Pereltsvaig 2006b, a, Zaroukian 2012, Matushansky 2015, Rothstein and Khrizman 2015): the inversion of the normal linear order between a cardinal and a noun with the semantic effect of speaker uncertainty as to the exact quantity:

(19) a. pjat' časov
five hour-GEN.PL
five hours

b. časov pjat'
hour-GEN.PL five
about five hours

Possible in multiplicative complex cardinals, targeting the first multiplicand:

(20) a. tysjač sorok rabočix
thousand.PL.GEN forty worker.PL.GEN
about 40,000 workers

b. *rabočix sorok tysjač
worker.PL.GEN forty thousand.PL.GEN
(possible as *of workers, 40,000* or *the working forty thousands*)

Possible in additive complex cardinals, targeting the lexical NP:

(21) a. rabočix sorok pjat'
worker.PL.GEN forty five
about 45 workers

b. *pjat' sorok rabočix
five forty worker.PL.GEN

The multiplicand can be fronted in mixed complex cardinals if it is a shared multiplicand of the additive component:

(22) a. *tysjač èтak million sto t_i devjat'sot pjat'desjat raz
thousand so million hundred nine.hundred fifty times.GEN

b. tysjač èтak sto pjat'desjat t_i soldat i oficerov
thousand so hundred fifty soldiers.GEN and officers.GEN
some one hundred and fifty thousand soldiers and officers

Matushansky 2015: Russian addition is coordination

Cross-linguistically unattested: coordinative syntax for multiplication

3.2. Multiplication and addition in F

Assuming that simplex cardinals denote numbers (type *n*, cf. Rothstein 2013, 2016, 2017, or *d*, see Scontras 2013, 2014, Kennedy 2013, 2015, and Ouwayda 2014), arithmetic operations involved in the formation of complex cardinals have to be encoded in F:
Rothstein's story is more complicated, she has two denotations for simplex cardinals

(23) a. $[\![F_{[ADD]}]\!] = \lambda n.\lambda m.\lambda o\,.\, o{=}n{+}m$
b. $[\![F_{[MULT]}]\!] = \lambda n.\lambda m.\lambda o\,.\, o{=}n{*}m$

Multiplication is cognitively very complex (more than addition or subtraction)

Yet **multiplication is systematically encoded without an overt exponent**

Furthermore, "natural" arithmetic is non-abstract:

- Dehaene 1997:187-193: a patient with acalculia (e.g., 3-2=2) clearly capable of interpreting and constructing complex cardinals or performing simple arithmetic operations when non-abstract (how many hours elapsed between 9am and 11am)
- Gilmore, McCarthy and Spelke 2007: abstract arithmetic addition is a fairly late development, which lags behind the ability to manipulate NP-internal complex cardinals or to estimate the results of adding or subtracting non-abstract quantities
- Spaepen et al. 2011: "even when integrated into a numerate society, individuals who lack input from a conventional language" "do not consistently extend the correct number of fingers when communicating about sets greater than three, nor do they always correctly match the number of items in one set to a target set when that target set is greater than three"
- McCrink and Spelke 2010: the core cognitive operations of addition and scalar multiplication are not precise (the way their symbolic counterparts are)

Potential explanation: F might originally involve this core arithmetic, which is then updated to its symbolic counterpart

Problem: this core arithmetic operates with small multipliers

Summary: it is impossible to exclude the hypothesis that there is an F. But it is very unlikely

4. NUMBER WORDS VS. SIMPLEX CARDINALS

Simplex cardinals that are not fully nominal are a closed class

Ionin and Matushansky 2006, 2018: unlike NP-internal cardinals, **number words show full syntactic uniformity**: unique form for the adjectival lower cardinals (no variation in gender or number) and lack of gender and number features capable of triggering agreement:

(24) Dva/*dve pljus tri budet/*budut četyre.
two.M/N/*two.F plus three be.FUT.3SG/be.PAST.PL four
'Two plus three will be four.'

If NP-internal cardinals are derived from number words, we expect uniform behavior

Cross-linguistically cardinals can be shown to show properties of major lexical classes (see Donohue 2005):

- verbs, as in Seri (Moser and Marlett 1994) or in Samoan (Mosel and Hovdhaugen 1992)
- nouns or adjectives (Corbett 1978, Hurford 2003)

Corbett 1978: cross-linguistically, cardinals in any given language tend to form a continuum from the more adjectival lower cardinals to the nominal higher cardinals:

- agreement vs. inherent ϕ-features
- modification vs. genitive case assignment/construct state/ezafe

This is a historically determined generalization

Table 1: The Russian cardinal "squish"

	1	**2**	**3, 4**	**½ (pol)**	**5-100**	**many/few**	**1000**	**million**
inherent animacy								+
inherent gender							+	+
number on lex. NP	SG	PL		SG	PL			
case		paucal		ADN	ADN		ADN/GEN	GEN
number and animacy agreement	+	+	+					
gender agreement	+	+						

Table 2: The Spanish cardinal "squish"

	1	2-100	200-900	1000	*millon*+
gender agreement	+	–	+	–	–
indefinite article and plural morphology	–	–	–	–	+
genitive preposition	–	–	–	–	+

Table 3: The Classical Arabic cardinal "squish" (after Blake 1912)

	1 (2)	3-10	20-90	100+
post-nominal (like APs)	+	–	–	–
gender agreement	+	+	–	–
construct state	no	yes	indeterminate	yes
case assignment	–	genitive	accusative	genitive
number on the lexical NP	singular (dual)	plural	singular	singular

4.1. Potential objection 1: ordinals

Even though ordinals are clearly morphologically derived from cardinals (see Stump 2010 for the full complexity), they can exhibit variant behavior where it comes to suppletion:

(25) a. unan 'one': kentañ unan-ved Breton, Stump 2010
first one-ORD
'first' 'first'

b. unan-ved warn-ugent
one-ORD on-twenty
'twenty-first'

(26) a. daou 'two': eil Breton, Stump 2010
second
'second'

b. eil warn-ugent
second on-twenty
'twenty-second'

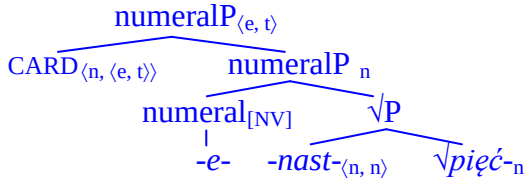
But this is not syntactic complexity, it is morphological (i.e., it is not about formal features of lexical items, but about lexical items (roots) themselves)

Categorially, all ordinals are the same

4.2. Potential objection 2: DM-style null affixes

The hypothesis (Marantz 1997, Embick 1997, Harley 1995, Harley and Noyer 1999, etc.) that roots have no lexical category can be extended to cardinals (Fassi Fehri 2018, Wągiel 2018 and maybe Klockmann 2019):

(27) a. Wągiel 2018



b. ⟦*-nast-*⟧=λn : INTEGER(n) . n+10
c. ⟦CARD⟧=λnλx: ATOM(x).|x|=n

The featural composition of the *numeral* head can vary in function of the simplex cardinal (or there can be an *a* or an *n* there)

Problem: different cardinals may have different featural specification (cf. Table 1-Table 3)

Russian is a case in point: there is only one cardinal (*pol-*) that is nominal, combines with a singular lexical NP and assigns adnumerative case to it

There are no other lexical items with this set of properties
The other semi-functional fraction, *četvert'* 'quarter' assigns genitive and has a different declension class

All this information needs to be encoded on **the phonologically null x head that can only be used with one root**

This is highly implausible as an analysis

5. THE DERIVATION OF NUMBER WORDS

In their mathematical use cardinals denote entities with a specific property:

(28) ⟦5⟧ = ιx . the number of digits on a limb of a mammal, the number of arms of a starfish, the number of lobes on a maple leaf, etc.

It's a property that sets have

Ionin and Matushansky 2006, 2018: NP-internal cardinals are semantically modifiers:

(29) $[\![\text{three}]\!] = \lambda P{\in}D_{\langle e, t\rangle} . \lambda x{\in}D_e . \exists S{\in}D_{\langle e, t\rangle} [\ \Pi(S)(x) \wedge |S| = 3 \wedge \forall s{\in}S\ P(s)\ ]$

(30) $\Pi(S)(x)$ is true iff partition
S is a *cover* of x, and
$\forall z, y{\in}S [\ z{=}y \vee \neg\exists a [a \leq_i z \wedge a \leq_i y]]$ (Forbidding that cells of the partition overlap ensures that no element is counted twice.)

(31) A set of individuals C is a *cover of a plural individual* X iff
X is the sum of all members of C: $\sqcup C = X$

This denotation makes it easy to achieve multiplication
But it cannot be right for languages where cardinals are predicates, there the basic type must be different

Ionin and Matushansky 2018 derive the names of numbers from the corresponding cardinal predicate or modifier by a nominalizer:

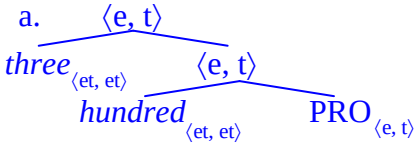
(32) a. NOMNUM $(\text{card}_{\langle e, t\rangle}) = \iota x . \forall y [|y| = x \rightarrow \text{card}(y)]$ predicate
b. NOMNUM $(\text{card}_{\langle\langle e, t\rangle, \langle e, t\rangle\rangle}) = \iota x . \forall g_{\langle e, t\rangle} . \forall y [{}^*g(y) \wedge |y| = x \rightarrow \text{card}(g)(y)]$ modifier

Names of numbers are nominal and definite (like proper names)

Question: how to construct a complex cardinal without a noun?

Two options:
- a null predicative PRO as the complement of the bottommost cardinal(s), with subsequent existential closure
- type-shifting the bottommost cardinal(s) to the predicate type

(33) a.



b. MOD2PRED $(M) = \lambda x . \exists P\ M(P(x))$

The former option is stipulative, the latter looks like what happens with inherently transitive nouns like *mother* when they are used without a complement (*When you become a mother…*)

This also means that only the option in (32a) is really needed

Problem: if something like (33) is available, how come there are languages where cardinals cannot be predicates?

There are also languages where cardinals cannot be NP-internal:

(34) Ná:ni-ha pokkó:l awáh tóklo-n hí:ca-li-:s. Koasati, Kimball 1991:358
man-PL ten AND two-SW see-1SG-PAST
'I just saw twelve men.'

The cardinal functions as a subordinate predicate; *see* is the main verb as the switch reference marker *-n* indicates
Multiplicative cardinals are formed with no overt marking; the element *awáh* is only used in cardinals (Kimball 1994:26)

6. CONCLUSION

Complex cardinals are constructed using linguistic means rather than abstract mathematical operations

Simplex cardinals do not seem to be derived from names of numbers

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