

The Syntax of Numeral Expressions

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The scientific community has long since adopted a fixed notation for representing mathematical numbers in an unambiguous way, namely the Hindu-Arabic decimal system. Although primarily written, the notational form may be spoken symbol-for-symbol as it is written. For instance the decimal expansion 3.14159, which is an approximation of the irrational number π , can be spoken in English as *three point one four one five nine*.

Natural language is equipped with its own linguistic conventions for expressing numbers distinct from the scientific language of numbers. For example, in English if a speaker wishes to express the number 222, they utter the expression *two hundred and twenty-two* rather than the sequence of digits *two two two*. The linguistic expression of a number (e.g., *two hundred and twenty-two*) is called a numeral. Numerals can be morphologically *simple* or *complex*. A simple numeral is a single morphological item.

(1) *Simple numeral*

English *seven, hundred*

French *sept, cent*

Arabic *sabʕ-, miʔat*

Russian *sem', sto*

A complex numeral is made up of a sequence of simple numerals with optional or obligatory intervening material. The grammar constrains the internal organization of a complex numeral. This internal organization determines the meaning of the complex numeral.

(2)	<i>Complex numeral</i>				
English	<i>seven</i>	<i>hundred</i>	<i>and</i>	<i>five</i>	
French	<i>sept</i>	<i>cents</i>	<i>(et)</i>	<i>cinq</i>	
Arabic	<i>sabʕu</i>	<i>miʕatin</i>	<i>wa-</i>	<i>xamsu</i>	
Russian	<i>sem</i>	<i>sot</i>	<i>(*ni)</i>	<i>pjat'</i>	

The complex numeral *seven hundred and five* in (2b) illustrates two fundamental mathematical operations encoded in the grammar: multiplication and addition.¹ This complex numeral is made up of three simple numerals, i.e., *seven*, *hundred*, and *five*, and its internal organization indicates how to interpret the complex numeral. The simple numerals *seven* and *hundred* combine to form the complex numeral *seven hundred*, which illustrates multiplication between the numerals *seven* and *hundred*, 7×100 . The complex numeral *seven hundred* and simple numeral *five* combine to form the complex numeral *seven hundred and five*, $(7 \times 100) + 5$.² This complex numeral has a different internal organization from the numeral *five hundred and seven* even though it is made up from the same parts. These examples demonstrate how, in principal, a grammar equipped with a class of simple numerals and two basic operations $\langle \times, + \rangle$, can express any positive whole number. The productiveness of this system strongly suggests that numerals are built up in the syntax and interpreted compositionally.

(3) *Assumption.* Simple numerals are lexical items. Complex numerals are constructed from simple numerals in the syntax and interpreted compositionally.

Further motivation in treating complex numerals as structured syntactic objects comes from case facts. Numerals can have case. In many case-marking languages, like Modern Standard Arabic, morphological case appears on simple numerals. The examples in (4) represent Arabic DPs in subject position, receiving nominative case.

¹ Other languages, encode subtraction as well. I will not discuss this operation as it seems to be cross-linguistically rare and languages which encode subtraction also encode multiplication and addition. Of note, in English we do use subtraction to mark time before the hour, e.g., *quarter to/of three* = two forty five.

² In English, addition can be overtly expressed by the conjunction *and* though not always, e.g., *seven thousand seven hundred*. In French, the use of a conjunction is heavily dispreferred. In Arabic, addition is always overtly expressed using the conjunction *wa-* ‘and’. In Russian using a conjunction to express addition is ungrammatical (Anna Verbuk personal communication).

(4) Arabic

- a. *ʔarbaʕ-at-u* *rijaal-in*
four-FS-NOM men-GEN
'4 men'
- b. *ʔarbaʕ-at-u* *ʔaalaaf-in* *wa-* *xams-u-* *miʔat-in* *rajul-in*
four-FS-NOM thousands-GEN and five-NOM hundred-GEN man-GEN
'4500 men'
- c. *ʔarbaʕ-u* *miʔat-i* *ʔalf-in* *rajul-in*
four-NOM hundred-GEN thousand-GEN man-GEN
'400,000 men'

Nominative case is never realized on the counted noun *rajul/rijaal* 'man/men'. It is realized on one of the numerals. For example, in (4c) *ʔarbaʕ-u miʔat-i ʔalf-in* 'four hundred thousand', the simple numeral *ʔarbaʕ-u* 'four' is marked with nominative, whereas the simple numerals *miʔat-i* 'hundred' and *ʔalf-in* 'thousand' are marked genitive. Without exception, within a multiplicative sequence of numerals, the first numeral is marked nominative and the numerals that follow it are marked genitive. This pattern repeats itself for each conjunct. The noun *rajul/rijaal* 'man/men' is marked genitive.³

Previous work by Hurford (1987) and recent work by Ionin and Matushansky (2004) argue that the transparent compositional semantics of numeral expressions and the case facts suggest that complex numerals are built up in the syntax. I will continue this line of reasoning and offer a new account that provides a uniform treatment of numerals based on the additional theoretical assumption in (5).

- (5) *Assumption.* A numeral has the same syntax and semantics whatever its function in the noun phrase: cardinal, ordinal, etc.⁴

³ There are instances, though few, in which the noun inflects for accusative case. For instance, if the noun follows a number between 11-99 or, as a sign of respect, if it is followed by a numeral between 100-999.

⁴ Other functions not discussed in this paper include *distributives* (e.g., two by two, three by three, in twos, in threes, etc.), *fractions* (one third, one tenth, etc.), and *multipliers* (two times, three times, four times, etc.).

Some initial definitions are provided in (6).

- (6) Cardinals numerals used to count or indicate quantity
 e.g., *There are twenty-six letters in the English alphabet*
- Ordinals numerals used to indicate the (relative) position in an ordered list
 e.g., *The twenty-sixth letter of alphabet is Z*

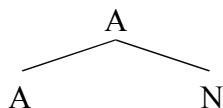
The motivation behind my account is the following observation: regardless of the difference in meaning between cardinals and ordinals, they are constructed using the same lexical items in the same multiplicative and additive patterns.⁵ Consequently, I assume that the numerals themselves have the same internal syntax and semantics regardless of their function. This suggests that the cardinal and ordinal meaning associated with a numeral is not internal to the numeral itself but is derived from the morphosyntactic structure the numeral merges into.

My analysis is set out in three proposals. The first describes the internal syntax and semantics of numerals. Numerals are phrases with their own internal structure and compositional semantics, distinct from the rest of the noun phrase, which reflects their mathematical character.

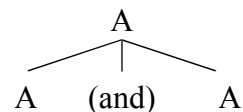
(7) Proposal 1

Numeral Internal Structure. Simple numerals divide into two classes, *low numerals* and *high numerals*. The former are adjectival and the latter are nominal. Complex numerals are constructed in the syntax using the two structures below, representing multiplication and addition. Complex numerals are adjectival. [Similar distinctions have been argued for in Hurford 1987, 2003) and Zweig (2004).]

a. Multiplicative Structure



b. Additive Structure



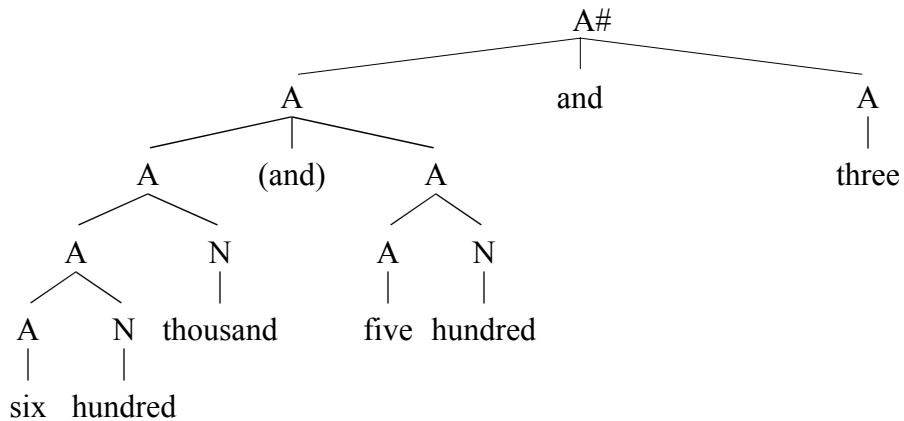
⁵ In some languages, minor morphosyntactic variation exists between cardinals and ordinals, for instance, the suffix *-th* in English; in some languages, the difference is positional as in Hebrew and Arabic, where ordinals above 20th have the same form as the cardinals but only occur post-nominally.

Semantics. Our formal language consists of four types s , e , t , and n , corresponding to the type of numerals. Our semantics contains the domain of interpretation $\mathcal{D}_n \subseteq \mathbb{N}$ on which the operations of multiplication \cdot and addition $+$ are naturally defined. For a low numeral A and high numeral N , where $[A]^{w,g}, [N]^{w,g} \in \mathcal{D}_n$, if $[A]^{w,g} = x$ and $[N]^{w,g} = y$, then:

- (i) $[A N]^{w,g} = x \cdot y \in \mathcal{D}_n$
- (ii) $[A \text{ (and) } A]^{w,g} = x + y \in \mathcal{D}_n$

The set of *low numerals* includes *one, two, three, ..., ten*, and the set of *high numerals* includes *hundred, thousand, million*, etc. Low numerals and high numerals combine in multiplicative and additive structures. In the syntactic structure interpreted as multiplication, illustrated in (7a), a low numeral A subcategorizes for a high numeral N as its complement. The merger forms an A . The coordinate structure in (7b) is interpreted as addition. Henceforth, for clarity, I will express the maximal numeral A as $A\#$. An example is given in (8).

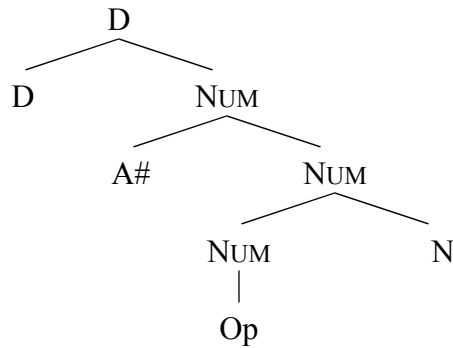
(8) six hundred thousand five hundred and two (600,503)



The following proposal describes the position of the numeral in the noun phrase. The relevant functional projection is the number phrase headed by NUM. Evidence for this projection has been provided for in Ritter (1988, 1991, 1992).

(9) Proposal 2

External Structure. The functional head NUM merges with a noun phrase complement N, either a count noun or a measure phrase, and the numeral A# merges into its specifier.



Semantics. The functional head NUM contains an overt or covert operator, which denotes a two-place relation and mediates the composition between the numeral A# and the noun phrase N. In other words, NUM is the locus for cardinal and ordinal interpretations. [A discussion of the actual semantic content of this node is postponed until section 3.]

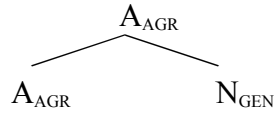
These first two proposals describe what numerals are, how they are constructed in the syntax, where they are located in the noun phrase, and how they interact with the lexical noun N. The next and last proposal explains the internal case pattern of complex numerals, as well as why the lexical noun following the numeral never bears nominative case.

(10) Proposal 3

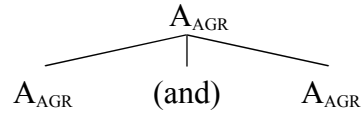
Case. The structural case assigned to a noun phrase containing a numeral values the head of that noun phrase, NUM. There is spec-head agreement between the numeral A# and head NUM. Case agreement is morphologically realized on each terminal head A in A#. Each head A in A# assigns structural case to its complement N. NUM assigns structural case to its noun phrase complement N.

The structures associated with multiplication and addition in (7) are repeated below in (11) with case agreement (marked AGR) and case assignment (marked GEN) indicated on each node.

(11) a. Multiplicative Structure

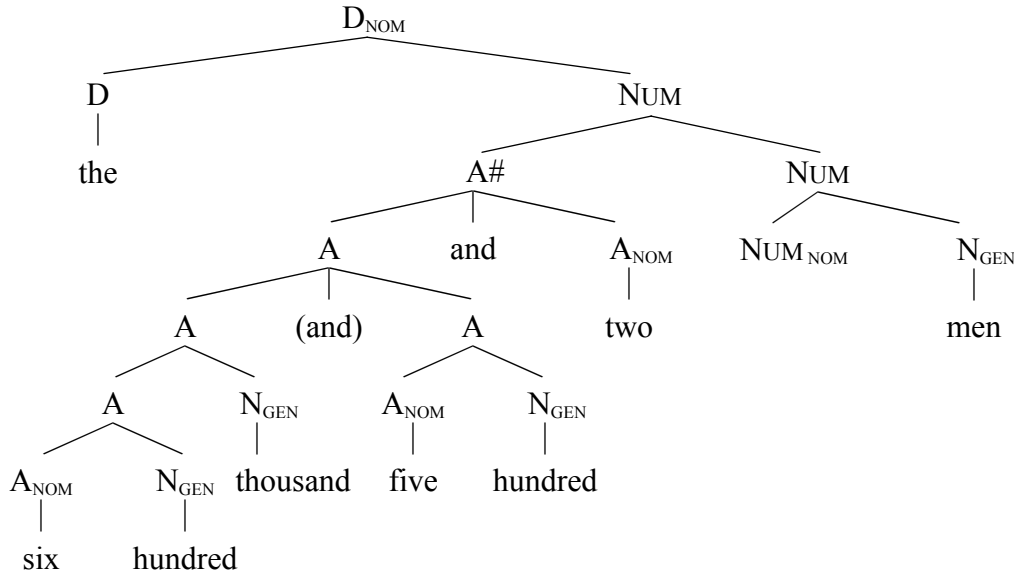


b. Additive Structure



In a structure like the example in (8), the case that appears on each low numeral A is the product of spec-head agreement between the A# and the case-valued head NUM. Each low numeral assigns genitive case to the high numeral N that it selects. To give an illustration of all three proposals at work, consider the noun phrase *the six hundred thousand five hundred and two men*, presented in (12).

(12) The six hundred thousand five hundred and three peanuts



This paper is divided into four sections. Section 1 presents previous analyses of the syntax and semantics of numeral expressions. In particular, I elaborate on a recent unified analysis by Ionin and Matushansky (2004) and an amendment to this analysis by Zweig (2004). In Sections 2 to 4, I provide arguments for my account, namely proposals 1-3. Section 2 presents data supporting the claim that there are two classes of simple numerals: low numerals, which are adjectival, and high numerals, which are nominal. I also provide evidence that complex numerals are adjectival. Section 3 is an examination of the parallel structure for cardinals and ordinals and their obvious semantic distinction. The semantics of ordinals provides a major argument against Ionin and

Matushansky (2004). In section 4, I argue that structural case can be assigned productively by A heads to their complements and that the dominant morphological form of this case is genitive. I further argue that in Semitic languages the marked word-order [noun numeral] obtains from the unmarked order [numeral noun] through head-to-head movement.

1. Previous Analyses

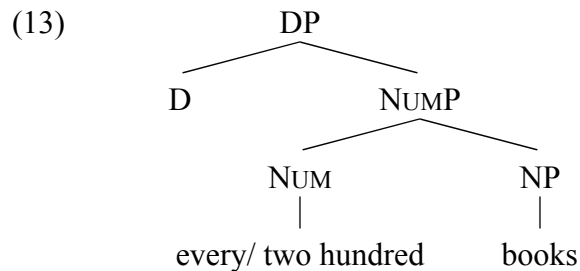
The syntactic and semantic literature on numeral expressions can be divided into three schools of thought. One proposal (Selkirk 1977, Hurdord 1987, Gawron 2002, too name just a few) is that numerals are in specifier position of NUMP or QP. Another view (Ritter 1991, Zamparelli 2000) is that complex numerals enter the syntax as terminals of functional heads, Q or Num. A third proposal (Ionin and Matushansky 2004) has emerged which argues that all simple numerals are exclusively nominal heads in a cascading structure. There are other non-syntactic accounts of numerals, focusing on the a semantics of counting (for instance, Krifka 1989), but I will focus on the syntactic accounts. Since my account situates numerals as specifiers, I forgo a discussion of this view and focus instead on the competing theories, notably the recent theory by Ionin and Matushansky (2004).

This section is divided into four parts. Section 1.1 is an outline of the functional head analysis (Ritter 1991). I give reasons why this account is incomplete. In section 1.2, I discuss a recent analysis put forth by Ionin and Matushansky (2004) (henceforth the nominal cascade analysis). Section 1.3 is a discussion of the strengths and weaknesses of this recent analysis. In Section 1.4, I briefly include recent results from Zweig (2004) in connection to the nominal cascade analysis.

1.1. Functional Head Analysis

Ritter (1991) proposes the structure in (13) for numerals in the noun phrase. The choice of this position is based on several coinciding observations, revolving around a syntactic analysis of the Semitic Construct State (Borer 1999; Ritter 1988, 1991). Numerals in Hebrew and Arabic have

a surface form and position like construct state nominals and they have the same distribution as certain quantifiers, like kol ‘every’, which also seem to enter in construct with adjacent nouns.⁶



There are two important points to make here. First, as Ionin and Matushansky point out, this theory would require we treat numerals as morphological compounds residing in the head NUM. This theory provides no mechanism for determining the construction and subsequent semantic composition of complex numerals. They also point out that numerals are not atomic to the syntax. For example, in English, the presence or absence of an indefinite coincides with the quality of the leftmost numeral. This is illustrated in (14).

- (14) a. A hundred and two books
 b. *A two books

This argument should be tempered. It assumes that the presence or absence of an overt indefinite is merely a product of the syntax. However, if the noun phrase *two books* is already indefinite, then the presence of another indefinite article would be semantically incompatible. It could be argued that the indefinite article *an* is a reduced version of the numeral *one*, which can co-occur with high numerals like *hundred*, *thousand*, *million*, etc., but not with other low numerals like *two*. There is also evidence that the morphology has access to numerals. There are processes which nominalize numerals to the extent that (i) they refer without the presence of an overt or elided noun, as in (15a,d); (ii) they take the indefinite, as in (15b); and (iii) they form compound-like modifiers with measure phrases, as in (15c).

⁶ It should be noted that Shlonsky (2004) has argued at length that numerals do not enter in construct with nouns in Hebrew or Arabic. He shows convincing arguments that Numeral Noun constructions allow intervening material, which is not permitted in a construct state construction. While Shlonsky (2004) argues against a construct state analysis of Numeral Noun constructions, he still adopts the view that numerals are heads of functional projections CardP (Cardinal Phrase) and OrdP (Ordinal Phrase).

- (15) a. There are four **twos** in this deck of cards and eight Δ in that one.
 b. He had a **twenty-seven** tattooed on his arm.
 c. I purchased two hundred **85-pound** sacks of grain
 d. Two **threes** make **six**

However, the problems with this theory go beyond these issues. The functional head analysis cannot account for the case facts for languages like Arabic and Russian; nor does it provide us with a structure that allows for a compositional analysis of a numerals meaning. So I reject this account not on the basis of it being falsifiable but because it provides an incomplete empirical account. It is also inconsistent with my initial assumption that the meaning of complex numerals is compositional.

1.2. Nominal Cascading Analysis

Ionin and Matushansky focus on the very question this paper is about, namely how to construct complex numerals in the syntax so that they can be interpreted compositionally and so that the case internal to numerals is also accounted for. Their account assumes all numerals are nominal heads of noun phrases. Here is a summary of the syntax and semantics they propose (16).

(16) Ionin and Matushansky

Syntax. Cardinals are generated as nominal heads N^0 which take NP complements, to which they assign case. In a conjoined structure, the complement of each NP numeral expression right-node raises.

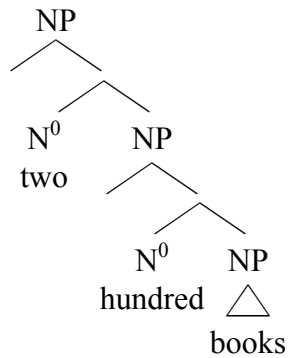
Semantics. Cardinals are modifiers of type $\langle et, et \rangle$, whose semantics is a straightforward application of partitions: $\llbracket n \rrbracket = \lambda P \in D_{\langle et \rangle} . \lambda x \in D_e . \exists S = \Pi(x) [|S| = n \wedge \forall s \in S. P(s)]$

The partition $\Pi(X)$ is defined as a set of (possibly plural) individuals such that:

- (i) $+ \Pi(X) = X$ (cover)
 (ii) $\forall z, y \in \Pi(X) [z=y \vee \neg \exists a [a \leq z \wedge a \leq y]]$ (disjoint)

The structure in (17) is an example of a multiplicative structure. The numerals *two* and *hundred* are each nouns and head a noun phrase. The N *hundred* selects and assigns case to the singular NP *book* as its complement. The N *two* selects and assigns case to the NP *hundred book*.

(17) Two hundred books



$$\begin{aligned}
 & [[\text{hundred books}]^{w,g}] \\
 & = [[\text{hundred}]^{w,g}([\text{books}]^{w,g})] \\
 & = (\lambda P \in D_{(et)}, \lambda x \in D_e. \exists S = \Pi(x)[|S|=100 \wedge \forall s \in S. P(s)])(\text{book}') \\
 & = \lambda x \in D_e. \exists S = \Pi(x)[|S|=100 \wedge \forall s \in S. \text{book}'(s)] \\
 \\
 & [[\text{two hundred books}]^{w,g}] \\
 & = [[\text{two}]^{w,g}([\text{hundred books}]^{w,g})] \\
 & = (\lambda P \in D_{(et)}, \lambda y \in D_e. \exists S' = \Pi(y)[|S'|=2 \wedge \forall s' \in S'. P(s')]) \\
 & \quad (\lambda x \in D_e. \exists S = \Pi(x)[|S|=100 \wedge \forall s \in S. \text{book}'(s)]) \\
 & = \lambda y \in D_e. \exists S = \Pi(y)[|S|=2 \wedge \\
 & \quad \forall s' \in S'. \exists S = \Pi(s')[|S|=100 \wedge \forall s \in S. \text{book}'(s)]]
 \end{aligned}$$

A requirement of Ionin and Matushansky's proposal is that the lexical NP which *hundred* selects is necessarily semantically singular, i.e., a set of atomic individuals (Link 1983). Crucially, this proposal assumes that the plurality of a numeral expression like *two hundred books* is a property of the numerals *two* and *hundred*, but not the lexical NP. So in English, the plural inflectional marker -s is a morphological marker on the entire plural noun phrase reflecting the plurality of the entire noun phrase. Ionin and Matushansky argue that languages like Finnish and Turkish, in which morphologically singular lexical NPs are used with numerals, in (18), support this view that lexical NPs are semantically singular.^{7, 8}

- (18) a. Yhdeksän **omena-a** puto-si maa-han
 Nine-NOM apple-PAR.sg fall-PAST.3SG earth-ILL
 'Nine apples fell to Earth' (Finnish)
- b. Yüz **keci** gel-di-ø
 hundred cat-SG come-PAST.3SG
 'A hundred cats came/arrived' (Turkish)

⁷ The lack of plural inflection in Finnish and Turkish does not constitute semantic evidence for semantic singularity or plurality. To name just a few, semantic tests for plurality (Chierchia 1998) include verbs that selecting plural or group-denoting NPs, like *gather* or *massacre*; quantifiers that select plural NPs, like *many*; coreference with plural anaphors.

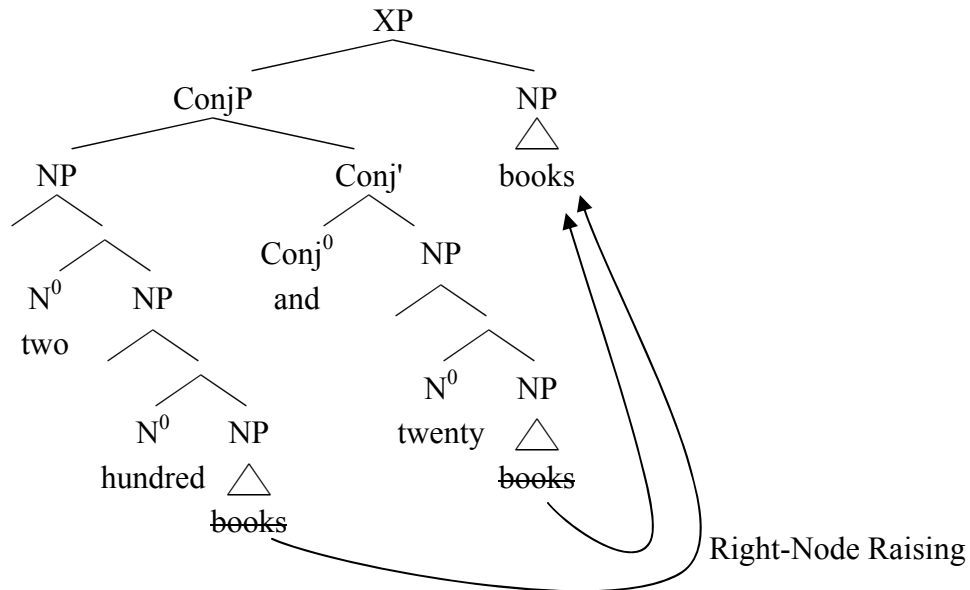
⁸ This proposal would need to say more to differentiate languages in which unmarked noun phrases are unspecified for semantic number (*general number*, Corbett 2000; Gil 1996), such as Tagalog and Maltese; languages in which the uninflected noun phrase has general number and the inflected form is exclusively plural, but there is no form that has singular semantic number, such as Kono; and languages in which inherently plural nouns, like collectives, can be inflected for singular semantic number (Ojeda 1992; Zabbal 2002), such Modern Standard Arabic and all its dialects.

Additionally, they argue that languages like Russian, in which regular plural suppletive forms do not arise with numerals, in (19), also support this view.

- (19) a. Po ulice šli ljudi / *čeloveki
 On street went-PL people-NOM person-NOM.PL
 ‘People walked down the street’ (Russian)
- b. Ona oprosila pjat’ čeloveki / *ljudej
 she question-PAST five-ACC person-GEN.PL people-GEN
 ‘She questioned five people’ (Russian)

Now consider the additive structure in (20). Here *two hundred books* has the same structure as it did in (17). The NP *twenty books* has a similar structure where the noun *twenty* selects and assigns case to the NP *books*. Alternatively, this could be construed as the N *ten* selecting the NP *books* and the N *two* selecting the NP *ten books*. The two NPs are conjoined and the NP *books* right-node raises outside the conjunction.

- (20) Two hundred and twenty books⁹



⁹ Ionin and Matushansky’s example (2004, (35)) is reproduced in (20) with one change: they consider the conjunct *and* to be optional. I have tested this with other native speakers and found that omitting the *and* was considered unnatural, although it can be reduced to a syllabic-n, e.g., *two hundred n’ twenty books*.

In this account, conjunction within a numeral is treated semantically as sum formation over two sets of plural individuals. The formal details that are provided are few. The denotation in (21) is mine and meant to describe what Ionin and Matushansky's semantics would have to look like.

$$\begin{aligned}
(21) \quad & \llbracket \text{two hundred and twenty books} \rrbracket^{w,g} \\
& = \llbracket \text{two hundred books} \rrbracket^{w,g} \oplus \llbracket \text{twenty books} \rrbracket^{w,g} \\
& = \{ x = y \oplus z \mid y \in \llbracket \text{two hundred books} \rrbracket^{w,g} \wedge z \in \llbracket \text{twenty books} \rrbracket^{w,g} \wedge AT(y) \cap AT(z) \neq \emptyset \} \\
& = \{ x = y \oplus z \mid y \in [\lambda y. \exists S = \Pi(y) [|S'|=2 \wedge \forall s' \in S'. \exists S = \Pi(s') [|S|=100 \wedge \forall s \in S. \text{book}'(s)]]] \\
& \quad \wedge z \in [\lambda z. \exists S = \Pi(z) [|S|=20 \wedge \forall s \in S. \text{book}'(s)]] \wedge AT(y) \cap AT(z) \neq \emptyset \}
\end{aligned}$$

What (21) says is that the denotation of *two hundred and twenty books* is the set of individuals x such that each x is the sum of two non-intersecting plural individuals, y and z , where y is in the denotation of *two hundred books* and z is in the denotation of *twenty books*. It is necessary that the conjuncts do not intersect, i.e., that they do not share atomic parts, $AT(y) \cap AT(z) \neq \emptyset$. Otherwise the statement *John bought two hundred and twenty books* could be true in a model in which John bought two hundred and ten books. More precisely, if $x = y \oplus z$ denotes the sum of y and z and y and z have ten books in common, then the sum x will only contain 210 different individual books and not 220 different individual book. Clearly, this is unwanted.

In order to justify their semantics and in particular this added criteria of non-intersectivity, Ionin and Matushansky rely on work by Heycock and Zamparelli (2003), whose work describes the readings obtained in conjoined plural NPs constructions, illustrated in (22).

- (22) His friends and colleagues came to the party
- a. A set of people each of whom is his friend *and* his colleague came to the party
 - b. A set of people each of whom is his friend *or* his colleague came to the party

Ionin and Matushansky suggest that the reading obtained for conjunction in complex numerals is identical to the *split* reading in (22b), so-called because the noun phrase refers to those entities that are either his friends or his colleagues but not both. Clearly their analysis depends on a fully split reading. However, unlike complex numeral expressions like *two hundred and twenty books*,

(22b) does not receive an exclusively split reading. Heycock and Zamparelli (2003, p.9) are explicit about this: (22a) and (22b) merely correspond to the polar readings of (22), but (22) admits a range of intermediate readings, e.g., in which some but not all his friends are also colleagues. It is also unclear whether the *and* in complex numeral expressions can be analyzed as non-Boolean *and* (Krifka 1990a). It is also clear that this is not just a problem for Ionin and Matushansky's analysis but for any compositional analysis of numeral expressions.

1.3. Discussion of the Nominal Cascading Structure

The strength of this proposal lies in its ability to account for morphological case patterns that are dependent on the right-most numeral in a numeral expression, without positing (or stipulating) any added mechanisms in PF. Evidence from Russian and Inari Sami is provided below.

(23) Russian

- a. dva šagA
two-NOM step-PAUC
'two steps'
- b. dvadcat' šagov
twenty-NOM step-GEN.PL
'twenty steps'
- c. dvadcat' dva šagA
twenty-NOM two-NOM step-PAUC
'twenty-two steps'

(24) Inari Sami

- a. kyehti / kulmâ / nel'i / vittâ / kuttâ päärni
two three four five six child-ACC.SG
'Two/three/four/five/six children'
- b. čiččâm/kávci /ovce /love /ohtnubáloh /kyehtnubáloh /čyeti... päärni
seven eight nine ten eleven twelve hundred child-PART.SG
'Seven/eight/nine/ten/eleven/twelve/one hundred children'

The morphological case that appears on the lexical NP differs depending on the numeral that immediately precedes it. If the numeral 2 through 4 in Russian, and 2 through 6 in Inari Sami, precedes the lexical NP, then the morphological case that appears on the lexical NP is different than if any other numeral preceded it. A similar dependency exists for Arabic for numerals 11 through 99. If these precede the lexical NP, the lexical NP bears accusative case and not genitive case.

(25) Arabic

xams-uuna rajul-a
 five-MP-NOM man-ACC
 ‘50 men’

There are three issues I would like to raise with this account for numerals. First and foremost, Ionin and Matushansky propose a semantics for numerals in which the notion of cardinality, i.e., counting individuals, is programmed directly into the denotation of the numerals themselves. As I described above, the structure Ionin and Matushansky assume for numerals requires right-node raising to obtain the correct surface form. This is represented linearly in (26), with a semantic breakdown.

- (26) a. two hundred and twenty books \approx [[two hundred ~~books~~] and [twenty ~~books~~]] books
 b. $[[\text{two hundred and twenty books}]^{\text{w,g}}] = [[\text{two hundred books}]^{\text{w,g}}] \oplus [[\text{twenty books}]^{\text{w,g}}]$
 c. $[[\text{two hundred books}]^{\text{w,g}}] = [[\text{two}]^{\text{w,g}}]([[\text{hundred}]^{\text{w,g}}]([[\text{books}]^{\text{w,g}}]))$
 d. $[[\text{twenty books}]^{\text{w,g}}] = [[\text{twenty}]^{\text{w,g}}]([[\text{books}]^{\text{w,g}}])$

The compositional semantics requires that the moved NP be interpreted in each conjunct in order to compute its denotation. This predicts that the semantics for numerals will always be additive; that is, the whole (220) is equal to the sum of the parts (200 + 20). While additivity is a property of cardinals, it is not a property of ordinals, distributives, or fractions. For example, the sentence *John is the three hundred and fifth man in line* does not mean John is the three hundredth man in line and fifth man in line. A different semantics for cardinals and ordinals is provided in section 3, one that assumes that the meaning of the complex numeral is obtained before it combines with

the noun phrase. Moreover, languages often use the same numeral system to express cardinals, ordinals, distributives, fractions, etc. It is unclear why cardinality, i.e., counting entities, should be built into the denotation of numerals. This suggests that cardinality is a primitive from which the other meanings are derived. My proposal deviates considerably from this point. I assume that counting and the natural arithmetical operations associated with numbers are primitives and that cardinality and ordinality are derived.

Second, I have already mentioned that Ionin and Matushansky's treatment of the coordination in complex numerals is problematic because it admits an overlap reading that seems to be absent from numerals, e.g., *two hundred and twenty soldiers stormed the castle* is true in a world in which two hundred and twenty distinct soldiers stormed the castle, and the conjunct *two hundred* and the conjunct *twenty* cannot refer to any common soldiers. Ionin and Matushansky attempt to motivate their treatment of conjunction by suggesting complex numerals have a split reading (Heycock and Zamparelli 2003). However, the semantics of conjunction within numerals seems fundamentally different from the semantics of conjunction between nominal elements in the noun phrase. In particular, conjunction inside a complex numeral lacks a distributive reading that is present in nominal conjunction within a noun phrase. (27) illustrates this difference.

- (27) a. Linguists and philosophers stormed the auditorium from the north entrance and the south entrance, respectively
= Linguists stormed the auditorium from the north entrance and philosophers stormed the auditorium from the south entrance
- b. #Two hundred and twenty soldiers stormed the castle from the north road and the south road, respectively
≠ Two hundred soldiers stormed the castle from the north road and twenty soldiers stormed the castle from the south road

Third, while the cascading nominal structure describes how simple numerals determine the morphological case on the lexical NP they select, the right-node raising analysis for complex numerals is incomplete. The example in (28) illustrates the problem.

(28) Arabic

[ʔarbaʕ-at-u ʔaalaaf-in ~~raju-l-in~~] wa- [xams-uuna ~~raju-l-a~~] rajul-a
four-FS-NOM thousands-GEN man-GEN and five-MP-NOM man-ACC man-ACC
'4050 men'

Ionin and Matushansky note that right-node raising is not possible when the common NP is assigned different case in the two conjuncts (Borsley (1983) and Franks (1993)). They claim that this never happens but in (28) it does. It should be noted that (28) is not a marked form, nor is it an exceptional form. Right-node raising cannot explain why the NP *rajul* 'man' surfaces with accusative morphological case *-a*, assigned by the conjunct *xamsuuna* 'fifty' and not genitive case *-in*, assigned by the conjunct *ʔarbaʕ-at-u ʔaalaaf-in* 'four thousand'. This problem extends to plural inflection, shown in (29) for Arabic.

(29) [ʔarbaʕ-at-u ʔaalaaf-in ~~raju-l-in~~] wa- [xams-at-u- ~~rijaal-in~~] rijaal-in
four-FS-NOM thousands-GEN man-GEN and five-FS-NOM men-GEN men-GEN
'4005 men'

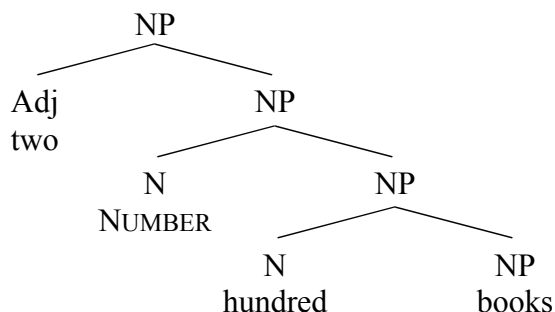
In (29) there is no case conflict. However, the conjunct *xamsatu* 'five' requires that the NP *rajul* 'man' be plural *rijaal* 'men'; whereas the first conjunct *ʔarbaʕ-at-u ʔaalaaf-in* 'four thousand' requires it be singular. Right-node raising does not provide an explanation of why government of the last conjunct should be preferred. For the plural, a possible explanation might be that the NP is semantically singular and plural morphology is realized at the level of the noun phrase. However, this explanation is problematic for the Arabic broken plural, which is formed from the singular using a non-concatenative morphological process which is arguably not inflectional or at least occurs before case morphology. What seems clear in both examples is that government of the last conjunct wins out.¹⁰

¹⁰ The case on the counted noun could be a result of adjacency with the numeral. In every case it appears that the case on the noun depends on the leftmost constituent of the numeral. A plausible account might be that at PF the morphological case that surfaces on the counted noun is determined by the numeral it is adjacent to rather than a head-complement case-assignment strategy.

1.4. Modified Structure

Zweig (2004) addresses several issues with the proposal in Ionin and Matushansky (2004). In so doing, he presents data from Hebrew and Luganda arguing that low numerals should be analyzed as adjectives. Zweig argues that in complex numerals, low numerals are adjectival modifiers of a covert nominal head NUMBER, following Kayne's (2003, 2005) analysis of quantifiers *few* and *many*. Zweig concludes that to accommodate the data he presents, Ionin and Matushansky's structure needs to be modified. His new structure is provided below in (30) for completeness.

(30) *Modified Structure*



Zweig entertains the possibility that numerals might be both adjectives and nouns but dismisses this possibility for two reasons. First, he observes that right-node raising is not possible from mixed nominal/adjectival modified NPs.

(31) *Impossible to right-node raise out of a mixed adjectival/nominal modified NPs*

- a. Our neighbor has both big and small houses
- b. Our neighbor has both brick and wood houses
- c. *Our neighbor has both big and wood houses

Consequently, numerals must either be nouns or adjectives. Second, he observes that adjectival numerals in Modern Hebrew seem to be in the construct state with the head noun. He notes that the construct state is reserved for noun phrases. However, this is not the case; the construct state is not reserved to noun phrases. It has long been observed that adjectives enter in the construct

state (Siloni 2002).¹¹ Without this restriction, there is no reason to conclude that complex numerals are nominal rather than adjectival, especially if right-node raising is not involved.

1.5. Summary

I examined two potential analyses of the syntax and semantics of numerals, the functional head analysis and the nominal cascade analysis. The functional head analysis, in which numerals are base-generated in a functional head position, e.g., NUM (Ritter 1991) or PD (Zamparelli 2000), treats numerals as syntactic atoms. This is incompatible with my underlying assumption that complex numerals are formed in the syntax and it also cannot account for numeral-internal case. The nominal cascade analysis (Ionin and Matushansky 2004) builds complex numerals in the syntax. Simple numerals are lexical nouns and they enter the syntax as nominal heads that select for and assign case to noun phrases. Complex numerals are formed through a combination of merger (multiplication) and conjunction (addition). The analysis explains many morphological case patterns. This is its strength. It also successfully describes the syntax and semantics for complex numerals via merger (multiplication), e.g., *two hundred books*. However, the analysis relies on right-node raising to describe the syntax and semantics of complex numerals formed by conjunction (addition), e.g., [*two hundred ~~books~~ and twenty ~~books~~*] *books*. I have pointed out (i) that the semantics of this analysis relies on the additive property of cardinals and is incompatible with the non-additive nature of ordinals; (ii) the conjunction *and* does not have the conventional properties associated to the so-called non-Boolean *and*, which is used between noun phrase; and (iii) that in Arabic case facts are inconsistent with a right-node raising analysis.

Zweig (2004) presents evidence that low numerals are adjectival. He argues that the structure in Ionin and Matushansky must be modified to take this into account. However, he maintains that complex numerals are nominals. I diverge from Zweig on this point.

¹¹ If indeed numerals are in construct in Hebrew. For an opposing view, see Shlonsky (2004).

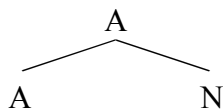
2. Adjectival Low Numerals and Nominal High Numerals

There are three parts to my first proposal (repeated below in (32)) that need to be addressed. The first part is that simple numerals split into two distinct morphosyntactic classes—what I call *low numerals* and *high numerals*. The second is that low numerals pattern like adjectives, and high numerals pattern like nouns. This coincides with parallel observations made in Zweig (2004). The third is that complex numerals pattern like low numerals, i.e., like adjectives. This last part is embodied in the syntactic structures provided below, in which low numeral are taken to head multiplicative structures. Once again, this assumes complex numerals are formed in the syntax as head-complement pairs or as conjoined pairs. A compositional semantics for this structure falls out as a straightforward isomorphism between the object language and the arithmetic over natural numbers \mathbb{N} .

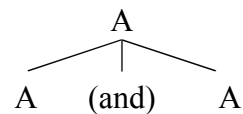
(32) Proposal 1

Numeral Internal Structure. Simple numerals divide into two classes, *low numerals* and *high numerals*. The former are adjectival and the latter are nominal. Complex numerals are constructed in the syntax using the two structures below, representing multiplication and addition. Complex numerals are adjectival. [Similar distinctions have been argued for in Hurford 1987, 2003) and Zweig (2004).]

a. Multiplicative Structure



b. Additive Structure



Semantics. Our formal language consists of four types *s*, *e*, *t*, and *n*, corresponding to the type of numerals. Our semantics contains the domain of interpretation $\mathcal{D}_n \subseteq \mathbb{N}$ on which the operations of multiplication \cdot and addition $+$ are naturally defined. For a low numeral *A* and high numeral *N*, where $[[A]]^{w,g}, [[N]]^{w,g} \in \mathcal{D}_n$, if $[[A]]^{w,g} = x$ and $[[N]]^{w,g} = y$, then:

- (i) $[[A N]]^{w,g} = x \cdot y \in \mathcal{D}_n$
- (ii) $[[A (\text{Conj}) A]]^{w,g} = x + y \in \mathcal{D}_n$

What follows are arguments for a split classification of numerals based on the following criteria. There is morphology that exclusively targets high numerals. Low numerals and high numerals distribute differently with respect to determiners. High numerals can occur in certain syntactic constructions in which low numerals cannot. I also present evidence that low numerals distribute like adjectives and in particular adjectival quantifiers. For each piece of evidence provided, I show that complex numerals pattern like low numerals and not like high numerals.

2.1. Evidence from English

In English, all count nouns and many mass nouns inflect for the plural -s. This is exceptionally productive and holds for all but a few historical plurals (e.g., *oxen*, *alumni*, *octopodes*). For a count noun, plural inflection signals that the noun refers to more than one entity with property N. For a mass noun, it signals that the noun refers to more than one variety of N.

- (33) a. John ate several eggss
b. John sampled several wines

Plural inflection appears on high numerals *hundred*, *thousand*, *million*, *milliard* (British), *billion*, etc. but not on low numerals *two*, *three*, *four*, etc. The plural of a high numeral refers to an indefinite number, i.e., hundreds \approx several hundred, rather than an precise number. The plural is equally productive on higher order nonce numeral words, like *zillion*, *bazillion*, *kadjillion*, etc.

- (34) *High numerals can inflect for the plural, Low Numerals cannot*
a. John ate hundreds of eggs
b. Hundreds of people gathered in the stadium
c. *John ate threes (of) eggs
d. *Threes (of) people gathered in the stadium

I set aside the issue of whether this is inflectional or derivational morphology and focus instead on the fact that the process targets one set of numerals but not the other. What seems clear is that this is not agreement morphology. Pluralizing a high numeral changes its semantics and enables

it to enter into syntactic constructions it otherwise cannot enter in, i.e., the pseudo-partitive (Selkirk 1977), e.g., *hundreds of wolves attacked Bob*, **(one) hundred of wolves attacked Bob*, **three of wolves attacked Bob*. This data suggests that high numerals pattern morphologically like count nouns in English and that they are distinct from low numerals.¹²

Furthermore, high numerals cannot occur in singular form without a preceding determiner, but low numerals can, shown in (35). High numerals can occur alone in singular form if preceded by an indefinite, whereas low numerals cannot co-occur with indefinites, shown in (36). Yet, both high and low numerals can co-occur with the definite determiner, illustrated in (37).

(35) *Low numerals can occur alone, High Numerals cannot*

- a. *John ate hundred (of) eggs
- b. *Hundred (of) people gathered in the stadium
- c. John ate three eggs
- d. Three people gathered in the stadium

(36) *High Numerals can co-occur with the indefinite, Low Numerals cannot*

- a. John ate a hundred eggs
- b. A hundred people gathered in the stadium
- c. *John ate a three eggs
- d. *A three people gathered in the stadium

(37) *High and Low Numerals can co-occur with a definite determiner*

- a. John ate the hundred eggs
- b. The hundred people gathered in the stadium
- c. John ate the three eggs
- d. The three people gathered in the stadium

¹² Low numerals do take plural inflection when they form distributives, e.g., *in three*, *in twelves*, which convey the meaning of groups of three or of twelve, and can alternatively be expressed as *three by three* and *twelve by twelve*.

High numerals can also enter into an iterative syntactic construction, of the form Ns and Ns (and Ns), that refers to greater and greater plural quantities. This construction admits high numerals and measure words only, e.g., *liter*, *dozen*, *kilo*, and not low numerals.

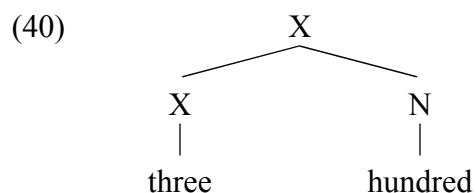
(38) *Iterative plurality*

- a. John bought hundreds and hundreds of books
- b. John bought hundreds and hundreds and hundreds of books
- c. John bought liters and liters (and liters) of water
- d. *John bought seven(s) and seven(s) of water

Turning to complex numerals, for example *three hundred*, it is straightforward to check that they behave exactly like low numerals.

- | | | |
|------|---------------------------------------|--|
| (39) | a. Cannot inflect for the plural | <i>*three hundreds</i> |
| | b. Cannot co-occur with an indefinite | <i>*a three hundred</i> |
| | c. Cannot form pseudo-partitive | <i>*John bought three hundred of books</i> |
| | d. Cannot form iterative plural | <i>*John bought three hundred and three hundred of books</i> |

This observation is embodied in the following structure, in which the low numeral X is the head governing the high numeral N. The structure retains the properties of X. Since the low numeral X (three) cannot pluralize, co-occur with the indefinite determiner, form a pseudo-partitive, or form an iterative plural, neither can the complex numeral X (three hundred). I will go on to argue that X is A.

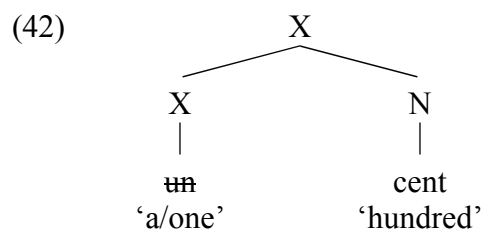


2.2. Evidence from French

In French, the underlying distinction between low and high numerals is difficult to tease apart. The plural data presented for English is not reflected in French. French has highly lexicalized plural agreement on a few numerals, but does not allow for plural high numerals as in English.¹³ Furthermore, unlike English, neither high nor low numerals co-occur with an indefinite article. This is shown in (41), where the data for *cent* ‘hundred’ are identical to the data for *sept* ‘seven’. Given the tests so far, French numerals all pattern alike.

- (41)
- | | | | | | | |
|----|-----------------------------------|-----|--------|-----------|---------|--------|
| a. | Jean | a | acheté | (les) | cent | livres |
| | J | has | bought | the-PL | hundred | books |
| | ‘John bought a/the hundred books’ | | | | | |
| b. | Jean | a | acheté | (les) | sept | livres |
| | J | has | bought | the-PL | seven | books |
| | ‘John bought (the) seven books’ | | | | | |
| c. | *Jean | a | acheté | un | cent | livres |
| | J | has | bought | a | hundred | books |
| d. | *Jean | a | acheté | un | sept | livres |
| | J | has | bought | a | seven | books |

This is not inconsistent with the proposed split between high and low numerals. I maintain that the division holds in French. The difference is that in French the low numeral *un* ‘a/one’ is never spoken before a numeral whereas in English it is always spoken as *a/one*.



¹³ For completeness, here are some additional facts about French plural agreement on numerals. Numerals *vingt* ‘twenty’ and *cent* ‘hundred’ show plural inflection when they are multiplied unless they are followed by another numeral. Numerals *million* ‘million’ and *milliard* ‘billion’ always show plural inflection when they are multiplied. All other numerals, including the high numeral *mille* ‘thousand’, never take plural inflection, although this is not a consistent fact. The presence or absence of the plural -s can be heard if the following lexical NP begin with a vowel.

Consequently, high numerals never surface alone. They always surface in a complex numeral phrase [_{XP} ~~the~~ *cent*] ‘a/one hundred’ and are always governed by a case-assigning head X.

French does have morphology that targets (certain) high numerals and not low numerals. The suffix *-aine/-ier* applies exclusively to the high numerals, including 10, 20, 30, ..., 90, 100, 1000. So for example, *centaine* = *cent* ‘hundred’ + *-aine* and *millier* = *mille* ‘thousand’ + *-ier*. The suffixed form *centaine* refers to a vague number in the hundreds, although there is a reading in which it refers to a group/unit consisting of a hundred entities. The French *centaine* patterns exactly like a noun, and in particular a measure word: (i) it can be singular or plural; (ii) like all French nouns, it requires a determiner; (iii) it enters in pseudo-partitive constructions. The plural form *centaines* can also be used in iterative plural constructions, as in (43).

- (43) a. Jean a acheté des centaines de livres
 J has bought INDEF.PL hundreds of books
 ‘John bought hundreds of books’
- b. Jean a acheté des centaines et des centaines de livres
 J has bought INDEF.PL hundreds and INDEF.PL hundreds of books
 ‘John bought hundreds and hundreds of books’
- c. Jean a acheté des litres et des litres d’ eau
 J has bought INDEF.PL liters and INDEF.PL liters of water
 ‘John bought liters and liters of water’
- d. *Jean a acheté des sept(aines) et des sept(aines) de livres
 J has bought INDEF.PL sevens and INDEF.PL sevens of books

We have already seen that high numerals inflect for case. Based on this evidence and these data I conclude that high numerals are nouns, albeit defective ones, and that affixes, like the English plural *-s* and the French *-aine* form non-defective Ns that pattern like measure words.

French also contributes evidence that numerals do not pattern like nouns in the syntax. This is fully consistent with my claim that high numerals are nouns, since I proposed that high numerals only surface within multiplicative structures headed by a low numeral X. A French noun phrase

must contain at least one determiner, quantifier, or numeral. In other words, French has no bare nouns. This is shown for count nouns in (44). The only exception besides predicate nominals in object position are noun phrases in proverbs and poetry.

(44) Count nouns

- a. le / un / *∅ livre est sur la table
 the a book is on the table
 ‘the/a book is on the table’
- b. les / des / plusieurs / quelques / trois / *∅ livres sont sur la table
 the.PL INDEF.PL many few three books are on the table
 ‘the/some/many/few/three books are on the table’

In (44a), the count noun *livre* ‘book’ must follow the definite determiner *le* ‘the’ or the indefinite *un* ‘a/one’. The sentence is ungrammatical if nothing precedes the noun *livre*. For the plural noun *livres* ‘books’, shown in (44b), either the plural definite determiner *les* ‘the’, the plural indefinite *des* ‘a’, adjectival quantifiers *plusieurs* ‘many’ and *quelques* ‘few’, or a numeral must come before the noun. Again, the sentence is ungrammatical if nothing precedes the noun *livres*. Count nouns require a determiner or quantifier within the same noun phrase; numerals do not. The data in (44) suggests then that numerals do not pattern like count nouns.

(45) Mass nouns

- a. La / *un / *∅ neige est belle
 the.F INDEF snow is beautiful
 ‘The snow is beautiful’ or ‘Snow is beautiful’
- b. *Les / *des / *plusieurs / *quelques / *trois / *∅ neige sont belles
 the.PL INDEF.PL many few three snow are beautiful

Mass nouns have more stringent requirements than count nouns. (45a) shows that mass nouns require the presence of a singular definite determiner. (45b) illustrates the ungrammaticality of other determiners, quantifiers, or numerals. Recall that French numerals can stand alone or with the plural definite. The data in (45) suggests then that numerals do not pattern like mass nouns.

Since numerals co-occur with the definite determiner, I conclude that they are not determiners. From the French data I also conclude that numerals are not nouns. More data will be provided in support of this conclusion below.

2.3. Semitic Word Order

In Arabic and Hebrew adjectives follow the noun phrase they modify and agree with that noun phrase in definiteness, gender, number, as well as case in Arabic. This agreement also partly holds for numerals that follow the lexical noun phrase. Arabic and Hebrew allow for prenominal and postnominal cardinal numerals. The prenominal position is the unmarked word order. For cardinals, the postnominal position is highly marked. (for Arabic, Wright 1933, volume 2, p. 230D; thanks to Shai Cohen for pointing this out for Hebrew). Ordinal numerals, however, must always follow the noun phrase.¹⁴ Relevant word orders are provided in (46).

(46) Arabic and Hebrew Word Order

Cardinals	Card Noun Noun Card	unmarked marked
Ordinals	Ord Noun Noun Ord	* unmarked
Adjectives	Adj Noun Noun Adj	* unmarked

(47) and (48) illustrate how adjectives agree with the noun they modify in definiteness, gender, and number, as well as case in Arabic. In (47a), the adjective *xaxam* ‘smart’ is marked with the definite determiner *ha-* ‘the’ in agreement with the definiteness on the noun *yelad* ‘boy/child’. (47b) agrees in definiteness but also gender. The adjective *xaxam* ‘smart’ is marked with the feminine suffix *-a* in agreement with the gender of the noun *yald* ‘girl’. Finally, (47c) shows number agreement between the plural noun *yeldot* ‘girls’ (literally, feminine children) and the adjective *xaxam* ‘smart’.

¹⁴ The agreement pattern between the cardinal and noun differs depending on the word order. I defer discussion of the agreement facts until section 4.

(47) *Adjectives in Hebrew*

- a. ha-yeled ha-xaxam kafac
the-boy the-smart jumped-3SM
'The smart boy jumped'
- b. ha-yald-a ha-xaxam-a kafc-a
the-girl-3FS the-smart-3FS jumped-3FS
'The smart girl jumped'
- c. ha-yelad-ot ha-xaxam-ot kafc-u
the-child-3FP the-smart-3FP jumped-3P
'The smart children jumped'

The data in (48) for Modern Standard Arabic is identical to Hebrew except for the additional case agreement facts and the position of the verb throughout. The noun is nominative and the adjective *saʕir* 'small' agrees with it in the nominative.

(48) *Adjectives in Arabic*

- a. daxal-a -l-walad-u s-saʕir-u
entered-3M the-boy-NOM the-small-NOM
'The small boy entered'
- b. daxal-at ʔal-bint-u s-saʕir-at-u
entered-3F the-girl-NOM the-smart-F-NOM
'The small girl entered'
- c. daxal-at ʔal-banaat-u s-saʕir-aat-u
entered-3F the-girls-NOM the-smart-FP-NOM
'The small girl entered'

Although cardinals are prenominal in contrast with adjectives, they can emerge in postnominal positions in marked utterances. The contrast in word order is presented for Hebrew (49) and Arabic (50).¹⁵

¹⁵ Semitic low numerals 1 ... 10 have inverse gender agreement, called *chiastic agreement* in the literature, with the noun or numeral that they govern. For example, if the numeral *θalaaθ* 'three' counts the masculine noun *walad*

(49) *Hebrew Prenominal and Postnominal Cardinals*

- a. shlosh meʔot ve- xamish-a ha-yelad-im kafc-u
three hundreds and five-F the-boy-MP jumped-3P
'The three hundred and five boys jumped'
- b. ha-yelad-im ha-shlosh meʔot ve- xamish-a kafc-u
the-boy-MP the-three hundreds and five-FS jumped-3P
'The three hundred and five boys jumped'

(50) *Arabic Prenominal and Postnominal Cardinals*

- a. daxal-a θalaaθ-u miʔat-i l-walad-i
entered-3M three-NOM hundred-GEN the-boy-GEN
'The three hundred boys entered'
- b. daxal-a l-ʔawlad-u θ-θalaaθ-u miʔat-i
entered-3M the-boy-NOM the-three-NOM hundred-GEN
'The three hundred boys entered'

The Arabic data in (50) is revealing. When a numeral occurs in pre-nominal position, it seems to govern the noun. The evidence for this is the genitive case and singular number that appears on the noun *walad* 'boy/child' in (50a). If another numeral had been used, say *xamsuuna* 'fifty', the noun would have been marked accusative singular, i.e., *l-walad-a*, and if *xamsatu* 'five' had been used, it would have been marked genitive plural *l-ʔawalad-i*.¹⁶ In (50b), however, the noun is plural and nominative and the numeral head *θalaaθ* 'three' necessarily agrees with the noun in definiteness and case. Note that it agrees with hundred in gender. This is the type of agreement we would expect from an adjective that does not inflect for number.

'boy/child', whose plural is *ʔawlad* 'boys/children', then *θalaaθ* 'three' is marked with the feminine suffix *-at*. So, *θalaaθ-at-u ʔawlad-u* 'three boys'. If the numeral *θalaaθ* 'three' counts the feminine noun, *bint* 'girl', whose plural is *banaat* 'girls', then *θalaaθ* 'three' is masculine/unmarked. So, *θalaaθ-u banaat-u* 'three girl'. Chiasitic agreement always occurs for low numerals. It should be noted that *miʔat* 'hundred' is lexically feminine and *ʔalf* 'thousand' is lexically masculine. In Hebrew, chiasitic agreement persists in marked postnominal cardinals but in Arabic it does not.

¹⁶ Shlonsky (2004) notes that in Arabic the definite determiner *ʔal-/l-* can mark the numeral, the numeral and noun, or just the noun. This is confirmed in Wright (1933) and Blachère et Gaudfroy-Demombynes (1952).

In contrast to cardinal numerals, Hebrew and Arabic ordinals necessarily surface in postnominal position and never in prenominal position. Ordinals between 1st and 10th have a morphological form different from cardinals 1 to 10, but ordinals over 10th have the same form as the cardinals. The only distinguishing property is surface word order. This is illustrated for Hebrew in (51).

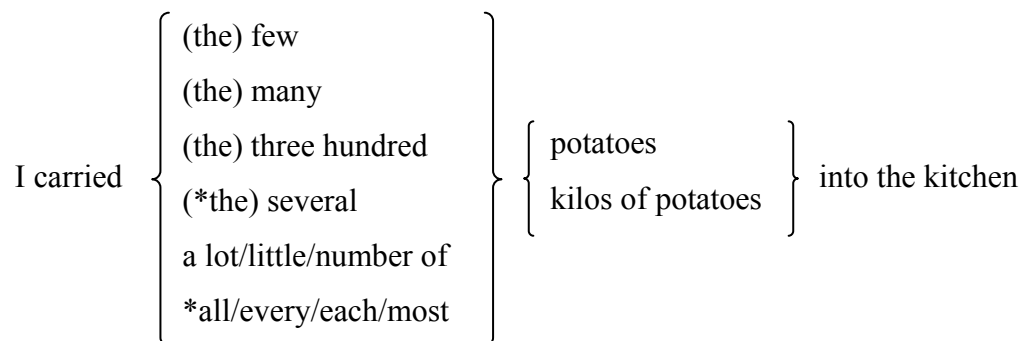
(51) *Hebrew ordinals are only postnominal*

- a. ha-yeled ha-shlosh me?ot ve- xamish-a kafac
 the-boy the-three hundreds and five-FS jumped
 ‘The three hundred and fifth boy jumped’
- b. ha-yald-a ha-shlosh me?ot ve- xamesh kafc-a
 the-girl-FS the-three hundreds and five-FS jumped-3FS
 ‘The three hundred and fifth girl jumped’

2.4. Anaphora

Having presented evidence from English and French that low numerals are adjectival and high numerals are nominal, and that complex numerals pattern like low numerals, and having further presented word order facts from Arabic and Hebrew that strongly suggest numerals pattern like adjectives, I turn now to the question of constituency. In particular, I turn to the question of whether the numeral and the following noun phrase form two separate constituents. In order to answer this question I look at anaphora and nominal ellipsis.

(52) *Numerals distribute like adjectival quantifiers*



A look at the distribution of cardinal numerals in (52) with respect to other quantificational items shows that the cardinal numerals are in complementary distribution with and distribute exactly like *few* and *many*. Kayne (2003, 2004) argues that they are adjectival quantifiers modifying a covert head NUMBER.

It is these adjectival quantifiers, *many* and *few*, that enter into an anaphoric relationship with the cardinal numerals. Examples include *that many*, *as many*, *so many*. Of the two quantifiers, the anaphoric behavior of *many* seems to be pragmatically more available than *few*. However, both are possible. It should be noted that these anaphora only apply to cardinals. But this is expected because, like cardinals, *many* and *few* refer to plural individuals and ordinals refer to singular individuals.

(53) *Count Anaphora*

- a. John bought three hundred_i marbles and Mary bought that many_i chocolates
- b. Four_i French diplomats visited that many_i Russian ambassadors
- c. Ten_i people bought tickets for the blockbuster and the usher was really surprised that that few_i people attended the screening
- d. The two_i drunks had that few_{i/j} drinks

The sentence in (53a) has the meaning that Mary bought the same number of chocolates as John bought marbles, namely three hundred.¹⁷ The antecedent of *that many* is *three hundred*. (53b) shows that this holds clause internally between subject and object positions. (53c,d) illustrates the same facts for *that few*.

The careful reader will observe that I left out any potentially misleading bracketing in (53), such as *three hundred_i ... [that many]_i* in (53a). This was purposefully done to avoid what I take to be a potential misanalysis of the data. The temptation might be to claim that *[that many]* forms a nominal constituent which refers to the numeral *three hundred* and therefore the numeral *three hundred* should be analyzed as a noun phrase. However, this does not explain the other numeral

¹⁷ The cardinal only receives an *exactly* reading and not an *at least* reading.

anaphora which contain *many* but no demonstrative, e.g., *as many*, *so many*, nor does it explain the nature of the wh-phrase *how many*.

These data support the claim that a numeral forms a constituent which is separate from the noun phrase it counts. Furthermore, if Kayne's analysis of *few* and *many* is correct, this also confirms that numerals are adjectival. Additional evidence supporting this conclusion is presented in (54). It is a well-established fact that, with a few exceptions, numerals cannot combine directly with a mass noun. A numeral first combines with a measure word to form a measure phrase. The anaphor *many* refers to a numeral and never a measure phrase whereas the anaphor *much* refers to a measure phrase and never a numeral.

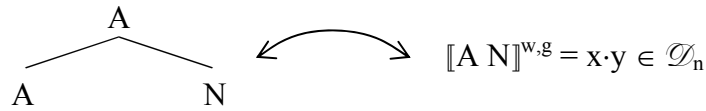
(54) *Mass Anaphora*

- a. John drank [three]_i pints of beer and Mary drank that many_i glasses of wine
- b. *John drank [three]_i pints of beer and Mary drank that much_i glasses of wine
- c. John drank [three pints]_i of beer and Mary drank that much_i wine
- d. *John drank [three pints]_i of beer and Mary drank that many_i wine
- e. John drank [[three]_i pints]_j of beer, Mary drank that many_i glasses of wine, Chuck drank that much_j cider, and Bill ate that many_i cheese doodles.

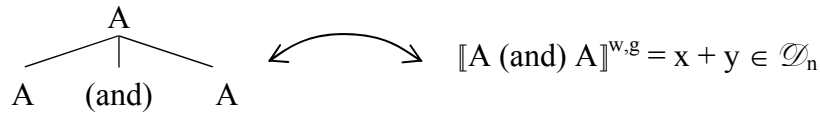
2.5. Semantics of Numerals

Proposal 1 includes a compositional semantics for numerals. This is simply a correspondence between the structure of numerals and the set of positive whole numbers. Intensional logic has three basic types, *s*, *e*, and *t*, to which I add the type *n*, corresponding to the natural numbers \mathbb{N} . An object of type *n* denotes an entity in the domain $\mathcal{O}_n \subseteq \mathbb{N}$, on which the binary operations of multiplication \cdot and addition $+$ are naturally defined. The interpretation function $\llbracket \]$, restricted to numerals, is a homomorphism between the multiplicative and additive syntactic structures and the natural operations of multiplication \cdot and addition $+$ on \mathbb{N} .

(55) a. Multiplicative Structure

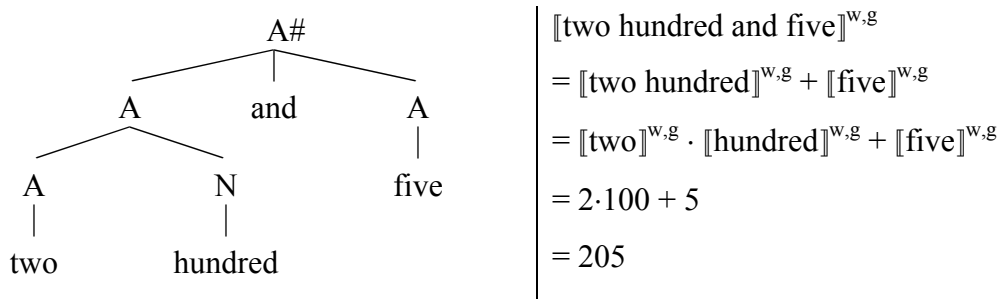


b. Additive Structure



So, the complex numeral *two hundred and five* has the syntactic form presented in (56), where *two hundred* is in a multiplicative structure and *two hundred* and *five* are in an additive structure.

(56) *Two hundred and five*



2.6. Summary

In this section I presented data in support of Proposal 1. Recall that Proposal 1 had three parts. First, there are two separate morphosyntactic classes, low numerals and high numerals. Second, low numerals are adjectival and high numerals are nominal. Third, complex numerals are built in the syntax using multiplicative and additive structure headed by adjectival low numerals. The result is that complex numerals always pattern like low numerals.

To support the proposal I gave distributional evidence from English, French, Arabic and Hebrew, as well as evidence from English anaphora. For English, I showed that low numerals lack certain properties associated with nominal elements that high numerals possess. I also showed that high numerals do pattern like nominal elements. French provided further support for my proposal. In

French, a noun phrase must contain either a determiner or a quantificational element. Unlike English, this includes mass nouns, abstract nouns, and generic nouns. There are no exceptions to this rule outside poetics, proverbs, and certain partitive constructions. Noun phrases containing a numeral can occur without a determiner. This argues against the nominal status of numerals. It should come as no surprise that in French numerals pattern like the adjectival quantifiers *plusieur* ‘many/several’ and *quelques* ‘few’. Evidence from Arabic and Hebrew shows that numerals can occur postnominally, a position reserved for adjectives and demonstratives. Finally, I presented data of numeral anaphora *many/much* which suggests that numerals are constituents, independent of the lexical noun they interact with.

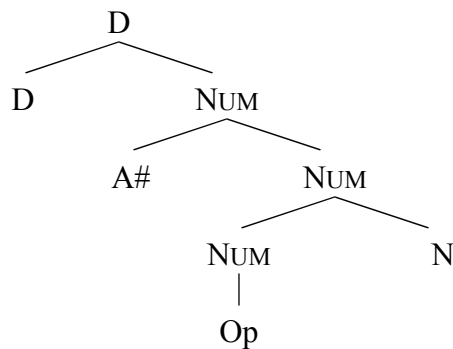
In the last subsection, I gave a semantics for complex numerals. Simple numerals denote natural numbers. The interpretation function $\llbracket \]$ maps the multiplicative and additive syntactic structures onto the binary operations of multiplication \cdot and addition $+$ on the domain of natural numbers. This provides a 1-1 mapping from form to meaning.

3. Cardinals and Ordinals

Proposal 1 states that numerals form adjective phrases, maximal projections A#. This leaves open the question of where numerals occur in the noun phrase and how they interact with what they count. Proposal 2 accounts for the syntactic position of numerals within the noun phrase, as well as the semantics that combines the numeral and the noun phrase that follows it.

(57) Proposal 2

External Structure. The functional head NUM merges with a noun phrase complement N, either a count noun or a measure phrase, and the numeral A# merges into its specifier.



Semantics. The functional head NUM contains an overt or covert operator, which denotes a two-place relation and mediates the composition between the numeral A# and the noun phrase N. In other words, NUM is the locus for cardinal and ordinal interpretations.

Throughout this section I assume the configuration given above. I defer discussion of the Arabic and Hebrew word order facts until next section.

3.1. What a Numeral Counts

Intuitively, it seems straightforward that underlying the relationship between the numeral A# and the noun phrase N is the concept of counting and measuring. What is not clear is precisely what is being counted. This relationship is not always transparent and need not be a direct counting of individual entities, even within the domain of what is conventionally called cardinality. When we examine other numerals, say ordinals, there is a sense in which something is being counted, but it is not entities. Ordinals also contribute a presupposition that cardinals do not. A variety of

examples are presented in (58) and (59). In what follows, I limit the discussion to cardinals and ordinals and leave distributives, multipliers, and fractions for future research.

(58) *Cardinals*

- a. Sergeant York captured one hundred and thirty two enemy soldiers
- b. John sampled three wines
- c. Four thousand ships passed through the lock
- d. Mary drank five pints of beer
- e. The flood lasted forty days
- f. Halley's comet passes every seventy-six years

Examples (58a-f) illustrate the uses of cardinal numerals. In (58a), the cardinal expresses the number of individual enemy soldiers. (58b) illustrates the counting of varieties of wine and not individual bottles of wine. At a wine tasting, there might be dozens of bottles of wine but only three kinds of wine. (58c) (Krifka 1990) illustrates event counting. The cardinal expresses the number of events in which a ship passed through the lock. The number of distinct ships is not at issue and the same ship may be counted multiple times if it passes through the lock more than once. In (58d), the cardinal expresses the measure of beer in pints that Mary consumed. It does not count dubious individuals like pint-entities. (58e) is an example of a cardinal that specifies the span of an interval of time. It measures the duration of the flood in units of days. In (58f), *every seventy-six years* refers to a set intervals, each one with a duration of *seventy-six years*. The sense here is that *every* is quantifying over a domain of intervals. The grammaticality of the sentence is also dependent on the quality of the predicate. The predicate *passes* is compatible with the distributive meaning contributed by *every*.¹⁸ From the perspective of cardinals and cardinal meaning, it is not clear that (58e) and (58f) have different semantics.

¹⁸ Zamparelli (2004) makes a similar observation for the phrase *every two miles*. He suggests that *two miles* acts like a measure phrase, measuring an abstract noun LENGTH. He also suggests that the semantics for this phrase should capture a meaning like (i).

(i) Every [two miles] LENGTH = λE [For all P such that P is the endpoint of a two-mile segment along a certain path, E is an event and E happens at P]

(59) *Ordinals*

- a. The hundred and fifth candidate won a prize
- b. Foul! There is a twelfth player on the football field
- c. The Romans executed every tenth slave
- d. Mary drank the fifth pint of beer in under a minute

Examples (59a-e) illustrate the uses of ordinals. Each example assumes a salient ordering, which I will show is a presupposition. (59a) presupposes a salient ordering of candidates. The ordinal picks out the candidate who occupies the 105th position in this ordering. The candidate's position in the order is specified, not the number of candidates. (59b) illustrates that the ordinal places an emphasis on the position in the ordering and not on the individual involved. In this example, the ordinal does not refer to a particular football player. In American football, only eleven players can be on the field during play. If a team has twelve or more players on the field during play, the team incurs a foul, called the twelfth man rule. No particular player is penalized. The team is held accountable for a twelfth man on the field. In (59c), the ordinal gets a sloppy reading. The quantifier *every* in *every tenth slave* ranges over a domain that includes slaves whose position in the ordering is a multiple of ten.¹⁹ (59d) combines the ordinal with a measure word. In contrast with the cardinal measure (58d), in this example the ordinal triggers a presupposition that there is an ordering of single pints of beer and it picks out the pint in the fifth position.

Cardinals and ordinals are in complementary distribution.²⁰ Proposal 2 accounts for this. There is only one syntactic position for a numeral, namely Spec-NUM, and one position for a numeral operator, namely NUM. An alternative semantic account could be that cardinals (except for *one*) require a plural argument while ordinals require a singular argument.

- (60)
- a. *John carried the tenth hundred bags
 - b. *John carried the hundred tenth bag

¹⁹ For some native speakers it is possible to obtain a super-ordinal meaning out of what I call a weak ordinal reading, *The Romans executed every tenth slave except for the fourth one, who escaped*. Speakers who find this sentence grammatical obtain the meaning that the fourth slave in the sequence of every tenth slave, i.e., the fortieth slave, escaped.

²⁰ The exceptions are *first*, *last*, and *next*. E.g., *John ate the first three donuts*, *Mary ate the next three donuts*, and *Bob ate the last three donuts*. I have no account for these elements.

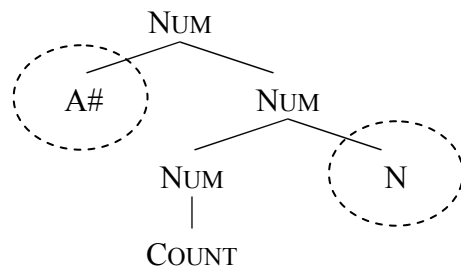
Clearly the relationship between the numeral and the noun varies. Two approaches to modeling this relationship are possible. We could assume a theory in which there is a distinct denotation for every semantic possibility, i.e., cardinals that count individuals, cardinals that count events, cardinals that count kinds, cardinals that measure mass, cardinals that measure a span. Under this view, the cardinal *three* could have up to five different denotations. It would also have a distinct denotation from the ordinal *third*. Alternatively, we could assume a theory in which numerals denote numbers and the relationship between numerals and nouns is expressed using a set of cardinal and ordinal operators. I will adopt this view. What follows is a presentation of the semantics for cardinals (following Krika 1989) and a preliminary semantics for ordinals.

3.2. Cardinal Semantics

There are two distinct readings for cardinals, a count reading and a measure reading, and each interpretation is associated with a distinct semantic operator. This is a simplification of the facts, since it conflates several of the readings in (58). The count operator will subsume the meanings in examples (58a-c), in which the quantity of individuals, events, or kinds, is counted out. The measure operator corresponds to examples (58d,e), in which a quantity of mass or a span is measured out.

In what follows, I assume Link's (1983) theory of plurality. To obtain the count interpretation, the functional head NUM selects for and merges with a noun phrase N, headed by a count noun. I use the term *count noun* here to refer to any noun whose denotation is a finite set of atomic elements, whether those elements are individuals, kinds, or events. The functional projection NUM is then merged with the numeral A#. The structure is shown in (61).

(61) Count Structure



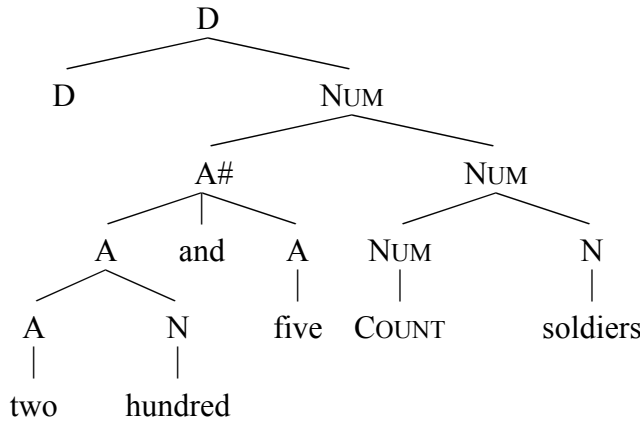
The denotation of the cardinal operator COUNT is a two-place relation of type $\langle \text{et}, \langle \text{n}, \text{et} \rangle \rangle$, which takes as its arguments the denotation of the noun phrase N, $[[N]]^{w,g} \in \mathcal{D}_{\langle \text{et} \rangle}$ and the denotation of the numeral A#, $[[A\#]]^{w,g} = n \in \mathcal{D}_n$. This operator returns the set of plural individuals with n atomic parts, a predicate of type $\langle \text{et} \rangle$. The details are provided in (62).

$$(62) \quad [[\text{COUNT}]]^{w,g} = \lambda P \in \mathcal{D}_{\langle \text{et} \rangle} . \lambda n \in \mathcal{D}_n . \lambda x \in \mathcal{D}_e . [x \in *P \wedge |\text{AT}(x)| = n],$$

where $\text{AT}(x) = \{ y \mid y \leq x \wedge \forall z (z \in P \rightarrow \neg z \leq y) \}$, the set of atomic parts of x

A derivation is presented for the noun phrase *two hundred and five soldiers*.

$$(63) \quad \text{Two hundred and five soldiers}$$



$$[[\text{COUNT}]]^{w,g} = \lambda P . \lambda n . \lambda x . [x \in *P \wedge |\text{AT}(x)| = n]$$

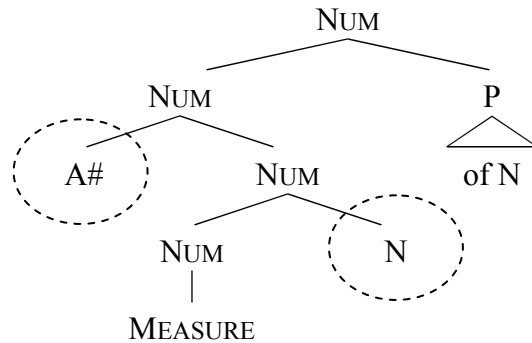
$$[[\text{soldiers}]]^{w,g} = \text{soldier}'$$

$$[[\text{two hundred and five}]]^{w,g} = 205$$

$$\begin{aligned} & [[\text{two hundred and five soldiers}]]^{w,g} \\ &= ([[\text{COUNT}]]^{w,g} ([[\text{soldiers}]]^{w,g})) ([[\text{two hundred and five}]]^{w,g}) \\ &= (\lambda P . \lambda n . \lambda x . [x \in *P \wedge |\text{AT}(x)| = n])(\text{soldier}')(205) \\ &= \lambda x . [x \in * \text{soldier}' \wedge |\text{AT}(x)| = 205] \end{aligned}$$

The following is a sketch of the syntax and semantics necessary for the measure reading. This sketch adopts much of Krifka (1989). To obtain the measure reading, the functional head NUM selects for and merges with a noun phrase N, headed by a measure word. I use the term *measure word* here to describe a noun that refers a unit of measurement, e.g., *pint*, *kilogram*, *year*, *meter*, whose denotation is a measure function μ from the domain of entities \mathcal{D}_e to the real numbers \mathbb{R} , $\mu : \mathcal{D}_e \rightarrow \mathbb{R}$ (cf. Krifka, 1989). The functional projection NUM is then merged with the numeral A#. An *of*-prepositional phrase P designating what is measured is then adjoined to NUM. The prepositional phrase P is optional for mass nouns, e.g., *five pints of beer*, *five pints of beer*. The structure is shown in (64).

(64) Measure Structure



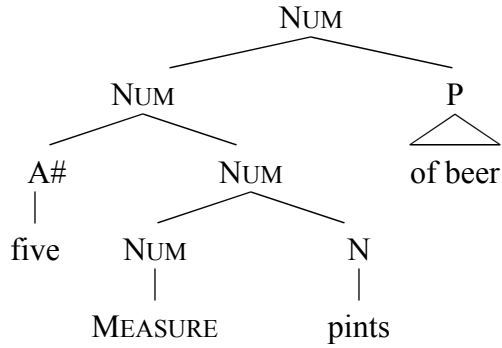
The denotation of cardinal operator MEASURE is a two-place relation of type $\langle\langle en \rangle, \langle n, et \rangle\rangle$, which takes as its arguments the denotation of the measure word N, $[[N]]^{w,g} \in \mathcal{D}_{\langle en \rangle}$, and the denotation of the numeral A#, $[[A\#]]^{w,g} = n \in \mathcal{D}_n$. It returns a predicate of type $\langle et \rangle$ (the set of individuals which have an N-measure of n). The details are provided in (65).

$$(65) \quad [[MEASURE]]^{w,g} = \lambda\mu \in \mathcal{D}_{\langle en \rangle} . \lambda n \in \mathcal{D}_n . \lambda x \in \mathcal{D}_e . [\mu(x) = n]$$

$$[[of-N]]^{w,g} = \lambda P \in \mathcal{D}_{\langle et \rangle} . \lambda x \in \mathcal{D}_e . [x \text{ is a material part of } P]$$

The prepositional phrase P is of type $\langle et \rangle$ and denotes the set of material parts of the mass noun N. It composes with the functional projection NUM via predicate modification. The relationship between mass nouns and their material parts is discussed in Link (1983), also Krifka (1989).

(66) *Five pints of beer*



$$[[\text{MEASURE}]^{w,g}] = \lambda\mu. \lambda n. \lambda x. [\mu(x) = n]$$

$$[[\text{pints}]^{w,g}] = \mathbf{pint'}$$

$$[[\text{five}]^{w,g}] = 5$$

$$[[\text{of beer}]^{w,g}] = \lambda x. [x \text{ is a material part of } \mathbf{beer'}]$$

$$[[\text{five pints}]^{w,g}]$$

$$= ([[\text{MEASURE}]^{w,g} ([[\text{pints}]^{w,g}]) ([[\text{five}]^{w,g}]))$$

$$= (\lambda\mu. \lambda n. \lambda x. [\mu(x) = n])(\mathbf{pint'})(5)$$

$$= \lambda x. [\mathbf{pint'}(x) = 5]$$

$$[[\text{five pints of beer}]^{w,g}]$$

$$= \lambda y. [[[\text{five pints}]^{w,g}(y) \wedge [[\text{of beer}]^{w,g}(y)]$$

$$= \lambda y. [\mathbf{pint'}(y) = 5 \wedge y \text{ is a material part of } \mathbf{beer'}]$$

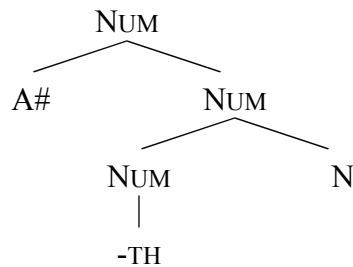
3.3. Ordinal Semantics

There are two readings for ordinals, a count reading and a measure reading. The count reading has a strict and a sloppy reading. A single operator is sufficient to obtain both readings. The sloppy reading surfaces by relaxing the properties of this operator. Recall that the strict reading corresponds to examples (59a,b), in which the ordinal determines the unique position in an ordering. The sloppy reading corresponds to example (59c), in which the ordinal determines a

domain for the quantifier *every* that includes those individuals whose position in the ordering is a multiple of the ordinal. The measure reading corresponds to example (59d).

To obtain either the strict or sloppy ordinal reading, the functional head NUM_O selects for and merges with a noun phrase N headed by a count noun phrase or a measure word N. I focus here on the semantics between ordinals and noun phrases. The functional projection NUM is then merged with the numeral A#. I assume that the locus for ordinal morphology is the head NUM_O . The structure is shown in (67); it differs from the cardinal structure in the quality of the operator.

(67) *Ordinal Structure*



The semantics of ordinals can be implemented in two ways, which at present seem to differ only in their ontology. Ordinals refer to a position in an ordered sequence. This much is clear. What is unclear is whether this position is determined (i) from the number of predecessors that come before an individual in the sequence or (ii) from a mapping between individuals and the natural numbers. In other words *the tenth slave* might refer to (i) the slave who follows nine other slaves in a sequence, i.e., the slave who has nine predecessors, or (ii) the slave who is mapped to the number 10. Ultimately, the question is whether we are referring to an individual relative to other individuals or an individual relative to a numerical position in an ordered list. These approaches differ in the types of orderings they allow. The first requires a linear order, whereas the second approach also accommodates a stratified partial order, which is like a linear order except that two or more individuals may be associated to the same position in the sequence. This is compatible with sentences like *John and Mary were the third people in line*. I will adopt the latter approach.

Ordinals trigger an extra meaning that cardinals do not, namely ordinal expressions presuppose the existence of an ordering. We can test that this is a presupposition in the regular way. In a

context where no order exists, using an ordinal results in a presupposition failure and undefined truth-conditions. If the ordinal triggers a presupposition, we expect that negation acts like a hole for the presupposition and that attitude verbs act like plugs for the presupposition.

(68) *Tests for Presupposition*

- a. Mary used the third elevator
- b. Mary did not use the third elevator
- c. John believes Mary used the third elevator

The examples in (68) confirm that the ordinal triggers a presupposition. Suppose we're in the lobby of a large office building and the elevators are numbered. Under negation (68b), a salient ordering of elevators is presupposed just like in (68a). In the given context, both (68a) and (68b) may be uttered felicitously. In contexts with no ordering on elevators, we get a presupposition failure and these sentences are neither truth-conditionally true or false. Furthermore, in (68c), an ordering of elevators need only be consistent with John's beliefs. No such ordering is required in the actual world.

(69) *Ordinal Presupposition*

There exists an ordering function f from the set of individuals P onto an initial interval of the natural numbers. Formally, for some $n \in \mathbb{N}$, where $I_n = [1, n] \subseteq \mathbb{N}$ is an initial interval in \mathbb{N} , there is a function $f : P \rightarrow I_n$. The function f associates to each individual a natural number in the interval I_n . Since the natural numbers have a natural ordering, the function f induces a partial order on P , written \leq_P , defined as $x \leq_P y$ iff $f(x) \leq_{\mathbb{N}} f(y)$. If f is 1-1, then \leq_P is a linear order. Otherwise, \leq_P is a stratified partial order.^{21, 22}

The denotation of the ordinal operator -TH is a two-place relation of type $\langle \text{et}, \langle n, \text{et} \rangle \rangle$, which takes as its arguments the denotation of the noun phrase N , $[[N]]^{w,g} \in \mathcal{D}_{\langle \text{et} \rangle}$ and the denotation of the numeral $A\#$, $[[A\#]]^{w,g} = n \in \mathcal{D}_n$. This operator returns the set of individuals that are mapped by

²¹ It is straightforward to show that any subset A of the natural numbers, $A \subseteq \mathbb{N}$, is isomorphic to an initial interval I_n of the natural numbers.

²² For plural individuals, such as $[[\text{John and Mary}]]^{w,g} = j \oplus m$, we need only require that $f(j \oplus m) = f(j) = f(m)$. This means that j and m are equivalent $j \approx_P m$. *John and Mary are third* entails *John is third* and *Mary is third*.

the ordering function f to the number n corresponding to the n^{th} position in the order. The details are provided in (70).²³

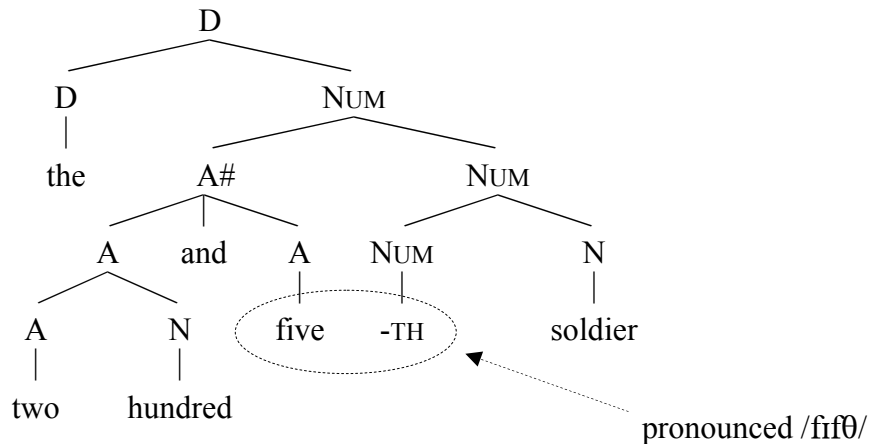
(70) *Ordinal Semantics*

Presupposition: there is at least one ordering function $f : P \rightarrow I_n$, for some $n \in \mathbb{N}$, with induced partial order \leq_p on P .

$$[[-\text{TH}]]^{\text{w},g} = \lambda P. \lambda n. \lambda x. \exists f [f(x) = n]$$

The ordinal semantics that I have presented says nothing about a salient order. If one exists, then it will coincide with the existential statement $\exists f$. In the example, *there is a twelfth player on the football field*, no salient order is presupposed to exist. This sentence is true in case there is some ordering of the players such that one of the players is ordered twelfth. A derivation is presented for the noun phrase *the two hundred and fifth point*.

(71) *the two hundred and fifth point*



²³ Alternatively, the denotation of the ordinal operator could be implemented relative to the predecessors of an entity x . So, *the tenth slave* is the unique x such that there is a salient ordering of slaves and nine other slaves precede x in that ordering. The details are given in (i).

- (i) Presupposition: there is at least one ordering function $f : P \rightarrow I_n$, for some $n \in \mathbb{N}$, with induced partial order \leq_p on P . Let the set of predecessors of x relative to the order \leq_p be defined as $\text{Pred}_{\leq_p}(x) = \{ y \mid y \in P \wedge y \leq_p x \}$
- $$[[-\text{TH}]]^{\text{w},g} = \lambda P. \lambda n. \lambda x. \exists \leq_p [x \in P \wedge |\text{Pred}_{\leq_p}(x) \cup \{x\}| = n]$$

$$\llbracket \text{-TH} \rrbracket^{w,g} = \lambda P. \lambda n. \lambda x. \exists f [f(x) = n]$$

$$\llbracket \text{soldier} \rrbracket^{w,g} = \mathbf{soldier}'$$

$$\llbracket \text{two hundred and five} \rrbracket^{w,g} = 205$$

$$\llbracket \text{the} \rrbracket^{w,g} = \lambda P \iota x. P(x)$$

$$\llbracket \text{two hundred and fifth soldier} \rrbracket^{w,g}$$

$$= (\llbracket \text{-TH} \rrbracket^{w,g} (\llbracket \text{soldier} \rrbracket^{w,g})) (\llbracket \text{two hundred and five} \rrbracket^{w,g})$$

$$= (\lambda P. \lambda n. \lambda x. \exists f [f(x) = n])(\mathbf{soldiers}')(205)$$

$$= \lambda x. \exists f [f(x) = 205], \text{ where } f : \mathbf{soldiers}' \rightarrow I_n, \text{ for some } n \in \mathbb{N}$$

$$\llbracket \text{the two hundred and fifth soldier} \rrbracket^{w,g}$$

$$= \llbracket \text{the} \rrbracket^{w,g} (\llbracket \text{two hundred and fifth soldier} \rrbracket^{w,g})$$

$$= (\lambda P \iota x. P(x)) (\lambda x. \exists f [f(x) = 205])$$

$$= \iota x. \exists f [f(x) = 205], \text{ where } f : \mathbf{soldiers}' \rightarrow I_n, \text{ for some } n \in \mathbb{N}$$

In the sentence *the two hundred and fifth soldier danced*, a unique salient order f is understood. This either follows from (i) the semantics of the definite, requiring not only familiarity with the two hundred and fifth soldier but perhaps also with the ordering, or from (ii) the uniqueness requirement on the individual. For the set $\lambda x. \exists f [f(x) = 205]$ to contain a unique individual, there cannot be another order f' such that $f'(y) = 205$.

This definition buys us both the definite and indefinite reading of ordinality. The definite obtains when the definite determiner picks out the unique maximal element x and the indefinite obtains when there is no such uniqueness requirement.

I will briefly mention the sloppy reading now and leave the problem of the ordinals and measure phrases for future research. The sloppy reading obtains if the semantics of the ordinal operator are relaxed, modulo n . What this means is that rather than strictly requiring $f(x) = n$, the ordinal operator is defined for every multiple of n , i.e., $f(x) = kn$, for $k \in \mathbb{N}$.

(72) *Sloppy Ordinal Semantics*

Presupposition: there is at least one ordering function $f : P \rightarrow I_n$, for some $n \in \mathbb{N}$, with induced partial order \leq_p on P .

$\llbracket \text{-TH} \rrbracket^{w,g} = \lambda P. \lambda n. \lambda x. \exists f [f(x) = kn]$, where $k \in \mathbb{N}$.

The result is a set of individuals, which can serve as the domain of the quantifier *every*, in the example *the Romans executed every tenth slave*. This is partially supported the data in (73).

(73) *Scenario*. The Roman army invades a small village and takes one hundred slaves. They decide to decimate the slaves to crush their morale.

a. The Romans executed every tenth slave.

b. The Romans executed every tenth slave except the fourth one. He escaped.

In (73a), *every tenth slave* receives a sloppy reading. The Romans executed ten slaves, namely the tenth slave, the twentieth slave, etc. In (73b), *the fourth one* refers to the fourth slave in the sequence of slaves that were to be executed, i.e., the fortieth slave. However, the semantics outlined above do not explain the grammaticality of (74a,c) with respect to the ungrammaticality of (74b,d). I leave this also as an open question.

(74) a. The Romans executed every tenth slave

b. *The Romans executed each tenth slave

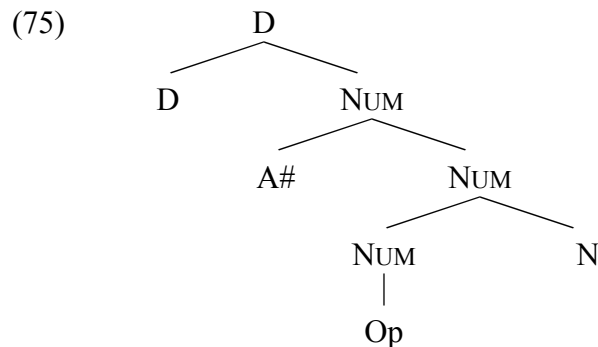
c. Every tenth slave escaped

d. *Each tenth slave escaped

3.4. Summary

Proposal 1 stated that numerals are phrases with their own internal structure and compositional semantics. The relationship numerals have with the abstract numbers they represent determines the syntax and semantics of how they are built up in the grammar. In this section I presented Proposal 2, which describes how the numeral interacts with the rest of the noun phrase it sits in. I propose that the relationship between a numeral and the following noun phrase, i.e., its function as a cardinal or as an ordinal, is determined by an operator generated in the head NUM.

The operator Op mediates the relationship between the numeral, which denotes a number, and the noun phrase N.



The motivation for this structure was the initial assumption repeated here in (76). In particular, cardinal and ordinal semantics are not encoded in the semantics of the numeral but are distinct from the numeral.

(76) A numeral has the same syntax and semantics whatever its function: cardinal, ordinal, etc.

Separating the semantics of the numeral (the denotation of A#) from the semantics of cardinality and ordinality (the denotation of Op) allows for a uniform treatment of numeral expressions as the linguistic expression of mathematical numbers. Count semantics, measure semantics, ordinal semantics are determined by the choice of Op.

I provide a sketch for the semantics of count and measure cardinals, adopting to Krifka (1989) and Gawron (2002). I also provide a semantics for ordinals, in which it is claimed that there is an ordinal operator -TH which presupposes an ordering on the set of individuals denoted by the counted noun N. The operator picks out the individual that is associated to the position in the ordering indicated by the numeral's value.

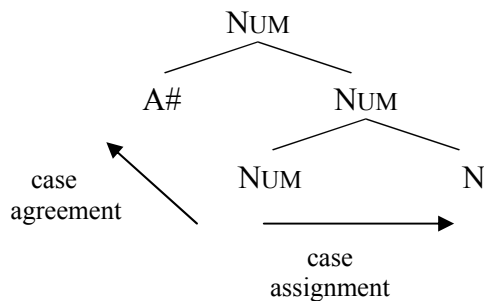
This account of cardinality and ordinality avoids the problems that were raised with Ionin and Matushansky's (2004) analysis, discussed in section 1.2 and 1.3.

4. Case

My third proposal is primarily concerned with numeral internal case, in languages like Arabic and Russian, as well as case on the lexical noun following the numeral. There are three parts to this proposal. First, the head of a noun phrase containing a numeral is the functional head NUM, and the structural case assigned to the noun phrase is realized on this head. The numeral A# is merged as the specifier of the head NUM and there is spec-head agreement between NUM and A#. In particular, A# agrees for case with NUM. Case is morphologically realized on each terminal head A in A#, i.e., the low numerals. Second, each low numeral head A assigns structural case to the high numeral noun N it governs. Third, the functional head NUM assigns structural case to the noun phrase it governs.

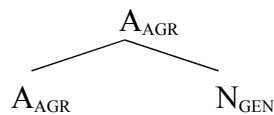
(77) Proposal 3

Case. The structural case assigned to a noun phrase containing a numeral values the head of that noun phrase, NUM. There is spec-head agreement between the numeral A# and head NUM. Case agreement is morphologically realized on each terminal head A in A#. Each head A in A# assigns structural case to its complement N. NUM assigns structural case to its noun phrase complement N.

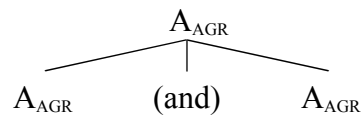


The structures associated with multiplication and addition are repeated below in (78) with case agreement (AGR) and case assignment (GEN) indicated on each node.

(78) a. Multiplicative Structure



b. Additive Structure



4.1. Case Assignment

Whatever analysis is proposed for numeral internal case and more generally for numeral internal morphological patterns, some aspect of that analysis must make reference to the lexical entry of the simple numerals. Notably, whether the simple numerals inflect for case, number, and gender. For example, in English, which is morphologically uninteresting for numerals, the cardinals only have one form and the ordinals have the same form except that they are marked with /-θ/ on the right edge of the numeral phrase. French is similar except that, while most cardinals don't inflect at all, some cardinals always inflect for number, e.g., *million* 'million', *milliard* 'billion', and a few only inflect for number if they are at the right edge of the phrase, e.g. *cent* 'hundred', *vingt* 'twenty'.

In what follows I give an account of numeral internal case in Arabic. In particular, I address the data in (79)-(87) which illustrates a recursive case pattern of NOM GEN also present in Russian. I postpone a discussion of the nominative case until the next subsection.

- (79) *ʔarbaʕ-at-u* *rijaal-in*
four-FS-NOM men-GEN
'four men' (Arabic)

For now, I ignore the inflection on the noun *rajul* 'man' and focus instead on the morphological patterns of the numerals. Low numerals in Arabic inflect for case and gender and optionally definiteness. In (79), it is the low numeral *ʔarbaʕ* 'four', and not the lexical noun *rijaal* 'men', that bears nominative case. There are two possible analyses of this data. The first is that *ʔarbaʕ* 'four' is the head of this noun phrase. The second is that the head of this noun phrase is covert and *ʔarbaʕ* 'four' is merely agreeing with its case.

A word about gender is necessary. In Arabic, feminine gender is marked /-at/; masculine gender is unmarked. Gender on numerals follows the so-called *chiastic* agreement pattern. If the thing the numeral agrees with is masculine, the numeral inflects in the feminine and if the thing the numeral agrees with is feminine, the numeral does not inflect, i.e., it has the masculine form. In

(79), the lexical item *rijaal* ‘men’ is masculine and the numeral *ʔarbaʕ-at* ‘four’ has the feminine form. In contrast, the *banaat* ‘girls’ in (80) is feminine and the numeral *ʔarbaʕ* ‘four’ has the masculine form.²⁴

- (80) ʔarbaʕ-**u** banaat-**in**
 four-NOM girls-GEN
 ‘four girls’ (Arabic)

Definiteness is conventionally marked on the lexical noun, as is (81a), but it can appear before the numeral phrase, as in (81b). The form in (81c) is considered marked but is available. Which form is the overt determiner is questionable. That all forms are realizations of determiners seems unlikely, especially in (81c). It is more likely a form of agreement with the definiteness on the D head. Thanks to Shai Cohen for pointing out to me that in Hebrew, definiteness only appears on the lexical noun. For the remainder of this discussion, I will ignore definiteness altogether.

- (81) Arabic
- a. ʔarbaʕ-at-**u** r- rijaal-**i**
 four-FS-NOM the men-GEN
 ‘the four men’
- b. ʔal- ʔarbaʕ-at-**u** rijaal-**i**
 the four-FS-NOM men-GEN
 ‘the four men’
- c. ʔal- ʔarbaʕ-at-**u** r- rijaal-**i**
 the four-FS-NOM the men-GEN
 ‘the four men’

²⁴ The gender of the nouns *rajul* ‘man’ and *bint* ‘girl’ are well-attested and could easily be tested if necessary using an adjective. Adjectives in Arabic have full agreement with the nouns they modify. So, we find *rajul-un jamil-un* ‘a beautiful man’ (no feminine agreement of on the adjective) and *bint-un jamil-at-un* ‘a beautiful girl’ (feminine agreement -at on the adjective).

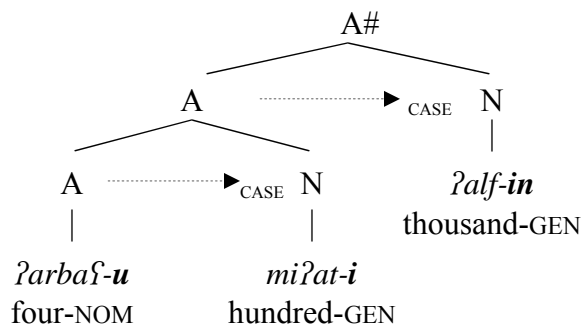
The high numeral *miʔat* ‘hundred’ is lexically feminine and the high numeral *ʔalf* ‘thousand’ is lexically masculine. While *miʔat* ‘hundred’ only inflects for case, *ʔalf* ‘thousand’ inflects for case and number. This explains the chiasitic forms of the numeral *ʔarbaʔ* ‘four’ in (82).

(82) Arabic

- a. *ʔarbaʔ-u* *miʔat-in* *rajul-in*
 four-NOM hundred-GEN man-GEN
 ‘400 men’
- b. *ʔarbaʔ-at-u* *ʔaalaaf-in* *rajul-in*
 four-FS-NOM thousand-GEN man-GEN
 ‘4000 men’
- c. *ʔarbaʔ-u* *miʔat-i* *ʔalf-in* *rajul-in*
 four-NOM hundred-GEN thousand-GEN man-GEN
 ‘400,000 men’

(82c) illustrates another piece of the puzzle. The case on *ʔalf* ‘thousand’ is identical to the case of *miʔat* ‘hundred’. Both are genitive, not nominative. It appears that what assigns case to *miʔat* ‘hundred’ is also assigning case to *ʔalf* ‘thousand’. This is consistent with the structure in (83). This is also consistent with Ionin and Matushansky’s nominal cascade structure.

(83) four hundred thousand



The adjective *ʔarbaʕ-u* ‘four’ selects the noun *miʔat* ‘hundred’ and assigns it case. The complex numeral *ʔarbaʕ-u miʔat-i* ‘four hundred’ is an adjective, which selects the noun *ʔalf* ‘thousand’ and assigns it genitive case. Low numerals also seem to trigger plural number agreement with the following numeral or noun. Since *miʔat* ‘hundred’ does not inflect for number, it appears in the singular form in numeral expressions.²⁵

That adjectives can select and assign structural case to a noun phrase complement is not without precedent. In English, it is clear that predicative adjectives are able to select for *of*-prepositional phrase complements and a wide-variety of clausal complements, but examples of adjectives that select for noun phrase complements without an intervening preposition are rare. Kayne (2005) notes that the word *near*, which is conventionally thought of as a preposition because it selects a noun phrase complement, has the properties of an adjective. He observes that *near* has both an adjectival comparative *-er* and superlative *-est* form, *nearer* and *nearest*, respectively.

- (84) a. John is near the park
 b. John is nearer than Mark
 c. John is nearest

As rare as adjectives directly selecting nominal complements is in English, in Arabic, adjectives do directly select for nominal complements in so-called *adjectival constructs* (Siloni 2002) (also referred to as the *construct of qualification* in prescriptive grammars of Arabic).

- (85) Arabic (Thackston 2000, 188)
- | | | | | | |
|----------------------------|-----------------|-----------|----------------|-----------|---------------|
| <i>ʔar-</i> | <i>raju-l-u</i> | <i>l-</i> | <i>ħasan-u</i> | <i>l-</i> | <i>wajh-i</i> |
| the | man-NOM | the | handsome-NOM | the | face-GEN |
| ‘the man handsome of face’ | | | | | |

²⁵ The numeral *miʔat* ‘hundred’ does have a plural form, *miʔuuna* ‘hundreds’; however, it is not clear that this plural is inflectional just as it is unclear if the plural *hundreds* in English is inflectional. It should be noted that the numeral *ʔalf* ‘thousand’ has two plural forms, *ʔaalaaf* ‘thousands’, which surfaces in numeral expressions where there is number agreement, and *ʔuluuf* ‘thousands’, which does not. Wright (1933, ii, 259D) reports that the forms *miʔuuna* ‘hundreds’ and *ʔuluuf* ‘thousands’ are used for indefinite numbers, hundreds and thousands.

(85) has the form noun + adjective + noun. The noun *rajul* ‘man’ is definite, masculine, and has nominative case. The adjective *hasan* ‘handsome’ agrees with this noun in definiteness, gender, and case, so it too has nominative case. The noun *wajh* ‘face’ however is in the genitive and appears to be the complement of the adjective *hasan* ‘handsome’. The English translation is a word-for-word except for the intervening preposition *of* which functions like the genitive. To further stress the head complement relationship between the adjective *hasan* ‘handsome’ and the noun *wajh* ‘face’, consider (86).

(86) Arabic

ʔar- rajul-**u** kaan-a ḥasan-**a** l- wajh-**i**
 the man-**NOM** was-3S handsome-**ACC** the face-**GEN**
 ‘the man was handsome of face’

4.2. Case Agreement

Complications arise when a complex numeral contains conjoined (additive) parts, each of which is a numeral itself. The low numeral in each conjoined element is marked with the nominative case. This is shown in (87).

(87) Arabic

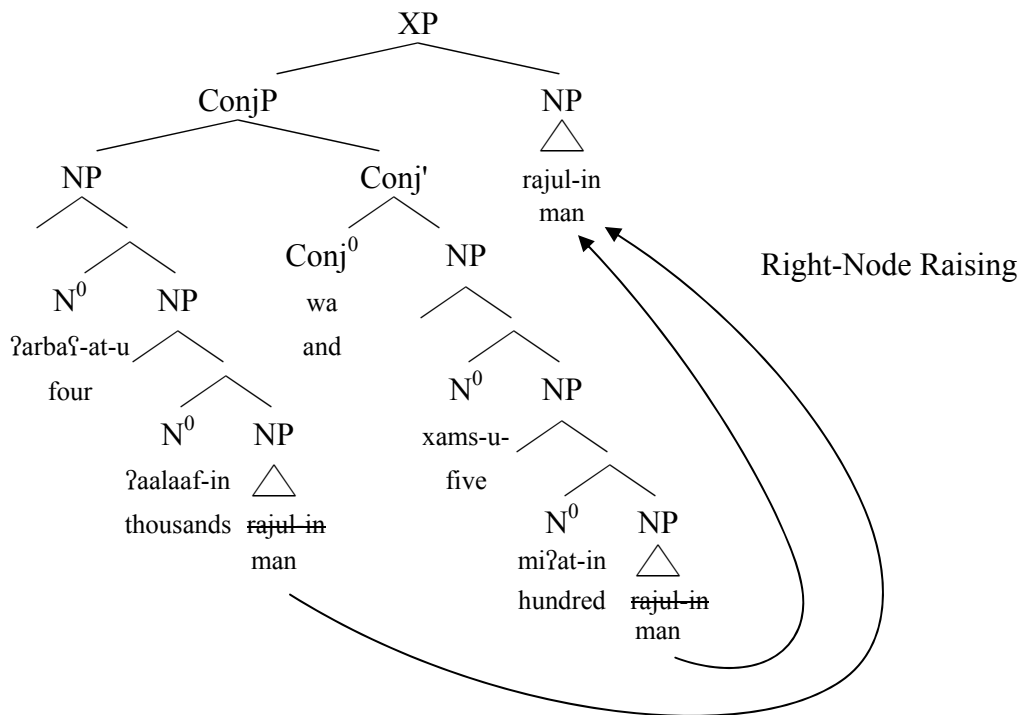
- a. ʔarbaʕ-at-**u** ʔaalaaf-**in** wa- xams-**u**- miʔat-**in** rajul-**in**
 four-**FS-NOM** thousands-**GEN** and five-**NOM** hundred-**GEN** man-**GEN**
 ‘4500 men’
- b. ʔarbaʕ-at-**u** ʔaalaaf-**in** wa- xams-**u**- miʔat-**in** wa- sitt-at-**u** rijaal-**in**
 four-**FS-NOM** thousands-**GEN** and five-**NOM** hundred-**GEN** and six-**FS-NOM** men-**GEN**
 ‘4506 men’

The numeral *ʔarbaʕat-u ʔaalaaf-in wa-xams-u-miʔat-in rajul-in* ‘four thousand five hundred men’ in (87a) is made up of *ʔarbaʕat-u ʔaalaaf-in* ‘four thousand’ and *xams-u-miʔat-in* ‘five

hundred’. Nominative case -u appears on *ʔarbaʔ-at-u* ‘four’ as well as *xams-u* ‘five’. In (87b), yet another conjoined element is added, namely *sitt-at-u* ‘six’, which also bears nominative case. So nominative case appears at least once in every conjunct.

Two possible analyses present themselves. The first (Ionin and Matushansky 2004) is that each conjunct in a complex numeral is a noun phrase and is directly case marked. In other words, the head of each noun phrase in (87a) *ʔarbaʔ-at-u* ‘four’ and *xams-u* ‘five’ receives nominative case. The nominal cascade structure for this hypothesis is presented in (88).

(88) *ʔarbaʔat-u ʔaalaaf-in wa-xams-u-miʔat-in rajul-in* ‘four thousand five hundred men’



The noun phrase *ʔarbaʔat-u ʔaalaaf-in wa-xams-u-miʔat-in rajul-in* ‘four thousand five hundred men’ has two heads, *ʔarbaʔ-at-u* ‘four’ and *xams-u* ‘five’. This conclusion should extend over to English as well but it fails to do so in (89).

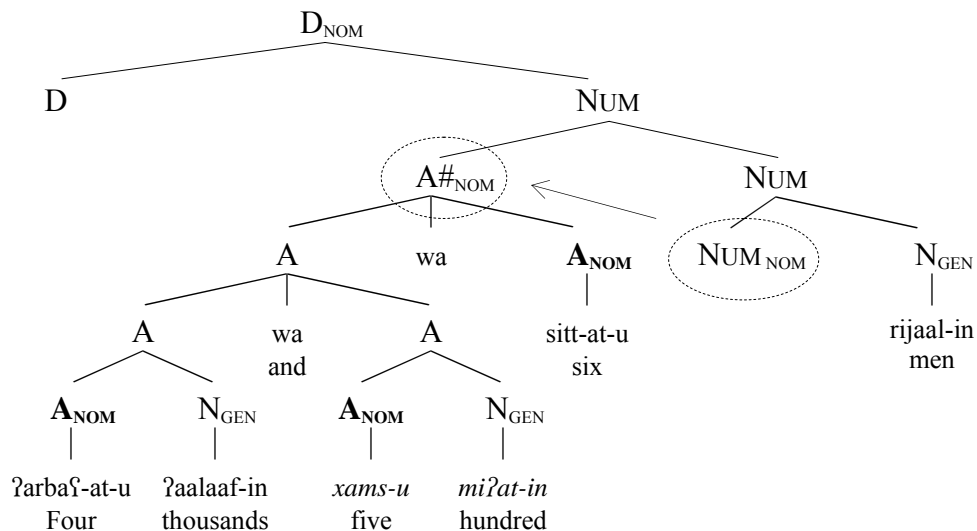
- (89) a. John won an astounding three hundred and five marbles from his friends
- b. John scored a career best three hundred and five points on the cricket pitch

In (89), the entire numeral is modified by an adjective, i.e., *astounding* and *career best*. In (89a), the adjective *astounding* is predicated of the total number of marbles John won. A distributive reading is unavailable. This sentence does not entail that winning five marbles is astounding. In (89b) (modified from an example in Gawron 2002), *career best* is predicated of the total number of points John scored on the cricket pitch. Here, too, a distributive reading is unavailable. The sentence does not entail that John’s career best is three hundred points and that it is five points. A distributive reading is available if *astounding* or *career best* are predicated of two conjoined noun phrases, as in (90). Under the hypothesis that a complex numeral contains two or more heads, and consequently two or more noun phrases, a distributive reading is predicted. I interpret the unavailability of the distributive reading as evidence that a complex numeral does not have multiple noun phrase heads.

- (90) a. John kissed the astounding linguists and philosophers
 b. John earned a career best five goals and three assists

The question regarding the nominative still remains. The second hypothesis is at the heart of Proposal 3. The nominative case that appears on *ʔarbaʕ-at-u* ‘four’ and *xams-u* ‘five’ in (87) is not case assignment but case concord arising from agreement between the functional head NUM and the numeral phrase A#.

- (91) Four thousand five hundred and six men



Nominative case must surface in the noun phrase. The functional head NUM is the head of the noun phrase and *rijaal* ‘men’ is its complement. Consequently, nominative case will not surface on *rijaal* ‘men’ and it cannot surface on the phonologically empty head NUM. The numeral phrase A# agrees with the head NUM. Nominative case surfaces on the low numeral adjectives A in A#.

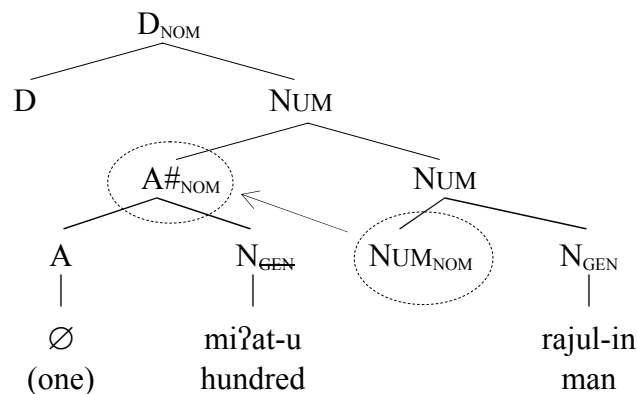
(92) Arabic

a. miʔat-**u** rajul-**in**
 hundred-NOM man-GEN
 ‘100 men’

b. ʔalf-**u** rajul-**in**
 thousand-NOM man-GEN
 ‘1000 men’

In (92), miʔat-u ‘hundred’ is inflected for nominative case, which shows that if there is no low numeral adjective in the numeral phrase A#, nominative case surfaces on the high numeral. In light of the present analysis, this suggests that nominative must surface in the noun phrase and this takes priority over the genitive on the high numeral. The structure is given in (93).

(93) miʔat-u rajul-in ‘100 men’



That agreement is occurring is further attested in so-called global agreement languages (Hurford 2003, 60). Numerals in languages like Finnish, Greek, and Russian (when the noun phrase is in the dative) exhibit global case agreement: every simple numeral in the complex numeral has the same morphological case.

(94) Russian (Hurford 2003, 61)

pjati- desjati tysjačam šesti- stam četyrnadcati rubljam
 5-SG.DAT 10-SG.DAT 1000-PL.DAT 6-SG.DAT 100-PL.DAT 14-SG.DAT roubles-PL.DAT
 ‘50614 roubles’

The numeral in (94) clearly shows global agreement. Every simple numeral within this complex numeral is marked for dative case DAT, rather than the pattern of NOM and GEN, as in (95).

(95) Russian

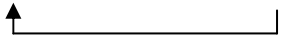
pjat- desjat tysjač šest- sot četyrnadcat rublej
 5-SG.NOM 10-SG.GEN 1000-PL.GEN 6-SG.NOM 100-PL.GEN 14-SG.NOM roubles-PL.GEN
 ‘50614 roubles’

It is unclear how a nominal cascade structure would simultaneously account for the regular case pattern in (95) and the global case pattern in (94). The case a numeral assigns would depend on the case it receives, which seems implausible. Proposal 3 has agreement between NUM and A#. In order to get both patterns we need only provide a language specific preference for dative case over genitive. So if NUM is valued as nominative then nominative appears on all the heads A in A# and the assigned genitive case appears on all the N in A#. If NUM is valued as dative, the dative appears on all the heads A in A# and all the N in A#. In other words, the structural case is never spelled out. This account seems more at home in an OT-framework implemented at the PF interface and perhaps that is the next step.

4.3. Word Order and Movement

Proposal 3 states that the head NUM checks structural case on its noun phrase complement. This explains why nominative case never surfaces on the counted noun in the word order Card Noun

and Ord Noun. In both cases, the noun phrase is a complement. If case checking is optional, i.e., NUM need not check the case of its complement, then the noun phrase is forced to move higher in the structure to get its case checked. Movement results in a different word order.

(96) D ... N ... A# ... NUM ... t


Recall that Arabic and Hebrew word order allows for prenominal and postnominal cardinals and only postnominal ordinals. The postnominal position, it was noted, is where adjectives appear on the surface. It was also pointed out that postnominal cardinals are highly marked. This is summarized in (46), repeated below in (97).

(97) Arabic and Hebrew Word Order

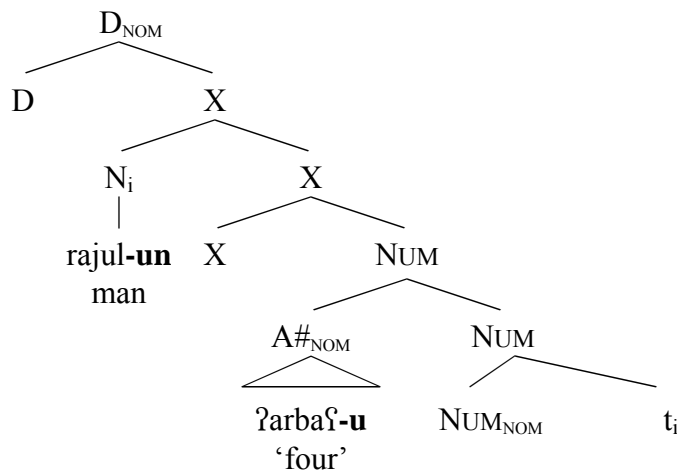
Cardinals	Card Noun Noun Card	unmarked marked
Ordinals	Ord Noun Noun Ord	* unmarked
Adjectives	Adj Noun Noun Adj	* unmarked

The contrast between prenominal numerals in (98a) and postnominal numerals in (98b,c) is given below. In (98a), the counted noun *rijaal* ‘men’ is genitive whereas in (98b,c) it is nominative.

- (98) a. *ʔarbaʕ-u rijaal-in*
 four-NOM men-GEN
 ‘4 men’
- b. *rijaal-un ʔarbaʕ-at-un*
 man-NOM four-FS-NOM
 ‘4 men’
- c. *ar- rajul-un ar- raabiʕ-at-un*
 the- man-NOM the four-FS-NOM
 ‘the 4th man’

The word order and case difference can be explained by assuming that when NUM is the operator COUNT, it need not check the case of its complement. The noun phrase complement must then move to a higher position to get its case checked. It moves to the first available spec position of some intermediate functional projection X and gets its case checked by spec-head agreement with the head X. Agreement values between X and N are identical to those for between NUM and A#. As a result, the N and A# are spelled out with the same morphology.²⁶

(99) rijaal-**un** ?arbaʕ-at-**un** ‘4 men’



For English and French, the head NUM always assigns case and as a result cardinals and ordinals are always prenominal.²⁷ In Arabic and Hebrew, when NUM is the operator COUNT or MEASURE, case assignment is optional but no case assignment is highly marked. When NUM is the operator -TH, it does not assign case and movement is obligatory.

In support of a movement analysis I provide this contrastive pair from Hebrew.

²⁶ The literature is filled with arguments for head-raising to D in Hebrew and Arabic, in conjunction with the analysis of the construct state (Borer 1999; Ritter 1988, 1991). Assuming a Kayne/Cinque model of functional projections, Shlonsky (2004) has in turn argued for phrasal movement within the Semitic noun phrase to recover the word order facts.

²⁷ There are examples of ordinal-like expressions in English and French in which the word order is *Noun Numeral*. E.g., *I chose curtain (number)three*, *Room (number) three hundred and five is down the hall*. To assimilate these examples into the present movement analysis requires an account of why ordinal morphology fails to apply. I have none at present.

- (100) a. *ha- yalda ha- yafa ha- shlosh me'ot ve- xamish-a*
 the girl the beautiful-FS the three hundred and five-F
 ‘The 305th beautiful girl’
- b. *ha- yalda ha- shlosh me'ot ve- xamish-a ha- yafa*
 the girl the three hundred and five-F the beautiful-FS
 ‘The beautiful 305th girl’/‘the 305th girl who is beautiful’

In (100a), the ordinal triggers the presupposition of an ordering on the set of beautiful girls and the ordinal picks out the 305th individual among the beautiful girls. The adjective *yafa* ‘beautiful’ attaches low, within the noun phrase headed by the count noun *yalda* ‘girl’, and consequently the adjective is within the scope of the ordinal operator -TH. In contrast, in (100b), the ordinal triggers the presupposition of an ordering on the set of girls, who need not all be beautiful, and it picks out the 305th individual among the girls who is also beautiful. Here the adjective *yafa* ‘beautiful’ attaches high, outside the scope of the ordinal operator -TH. Although (100b) is marked and requires the right intonational phrasing to be interpretable, it is available to native speakers.²⁸ Its English equivalent (101b) is equally marked.

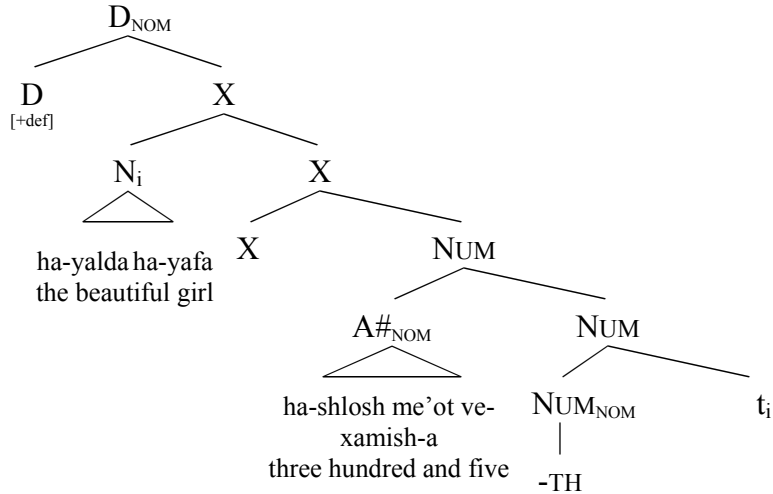
- (101) a. Bob hugged the [[third [beautiful woman]]]
 b. Bob hugged the [beautiful [third woman]]

These observations while not exclusive to a movement analysis are fully consistent with such an analysis. For completeness and clarity the relevant structures are presented in (102) and (103). In (102), the N *ha-yalda ha-yafa* ‘the beautiful girl’ is base-generated as the complement of the ordinal head NUM, which does not check its case, forcing the noun phrase to move to check case.

(102) Low Adjective

- ha- yalda ha- yafa ha- shlosh me'ot ve- xamish-a*
 the girl the beautiful-FS the three hundred and five-F
 ‘The 305th beautiful girl’

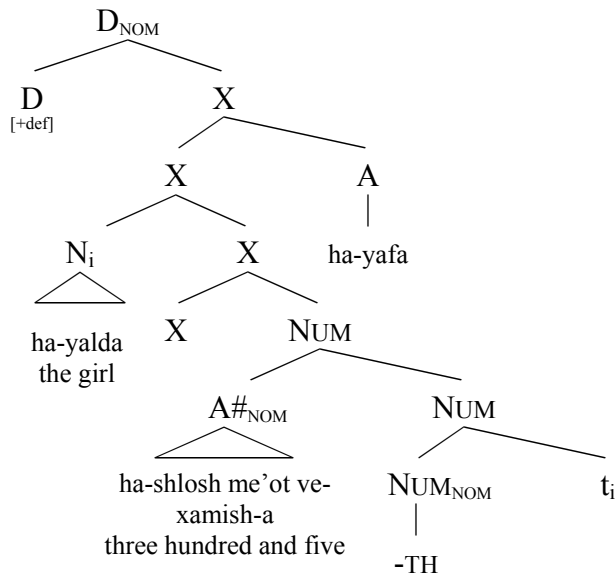
²⁸ Thanks to Michael Becker for pointing out that it is impossible to jam everything in (100b) within the same major phrase.



In (103), the N *ha-yalda* ‘the girl’ is base-generated as the complement of the ordinal head NUM, which does not check its case, forcing it to move to get its case checked. Finally, the A *ha-yafa* ‘the beautiful’ merges higher in structure.

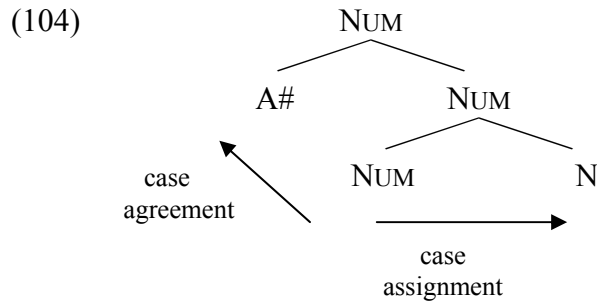
(103) High Adjective

ha- yalda ha- shlosh me’ot ve- xamish-a ha- yafa
 the girl the three hundred and five-F the beautiful-FS
 ‘The beautiful 305th girl’/‘the 305th girl who is beautiful’



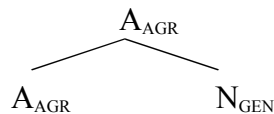
4.4. Summary

Numeral-internal case patterns promote the view that numerals have an internal structure. Any internal structure proposed for numerals must be compatible with these case patterns. Proposal 3 provides an account of case for the numeral-internal structure given in Proposal 1.

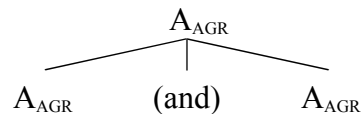


I assume that the head of a noun phrase containing a numeral is the functional head NUM, rather than the counted noun phrase N. The numeral phrase A# stands in a spec-head relationship with NUM and there is spec-head agreement between A# and NUM. Spec-head agreement is reflected on each terminal A in A#, i.e., each low numeral head A in A#. The case value of NUM surfaces on each terminal in the numeral. The low numeral heads A in turn check structural case on their complement high numeral N. The emergent case pattern is repeated in (105).

(105) a. Multiplicative Structure



b. Additive Structure



This case pattern reflects what Hurford (2003, 60) calls local agreement. An alternative pattern attested in languages like Russian, Finnish, and Greek, is global agreement, in which a single case appears uniformly on all terminals in the numeral. Accounting for local and global case is especially difficult in a strictly assignment-based account of case. An agreement-based account of case allows more latitude for realizing case.

Finally, the functional head NUM selects the complement noun phrase N. If NUM does not check the case of its complement, then the complement N must move. In this sense, a defective NUM triggers movement. In English and French, NUM obligatorily checks the structural case of N. In

Arabic and Hebrew cardinals, this is optional and when case is not checked on the complement noun phrase N, the N moves to a higher position to get its case checked. For Arabic and Hebrew ordinals, NUM never checks the case of N and it moves to get its case checked.

5. Conclusion

The internal case patterns and transparent compositional meaning of numerals promote the view that numerals have a complex internal structure (cf. Hurford 1987, 2003; Ionin and Matushansky 2004; Zweig 2004) and that this structure is constrained by the grammar. In this paper, I argued for an account of the syntax of numerals in which numerals are distinct from the rest of the noun phrase. In particular, I proposed that numerals have their own syntax and semantics, reflecting their correspondence with the natural numbers and the arithmetic of the natural numbers, namely the operations of multiplication and addition. Complex numerals are built up in the syntax from lexically simple numerals using two recursive structures: a structure denoting multiplication and the other, addition. This proposal maps the numeral-internal syntactic structure to the arithmetic of numbers. It treats numeral-internal coordination as mathematical addition and not as Boolean or non-Boolean coordination, which I argued is problematic. It is also consistent with the view that the internal meaning of numerals is independent of their function: a numeral is the linguistic expression of a natural number; it is neither a cardinal nor an ordinal until it merges into a noun phrase. Numerals denote natural numbers. The term cardinal or ordinal refer to the function of the numeral in the noun phrase and it is argued that this function is handled outside the numeral. Throughout I demonstrated how Ionin and Matushansky's (2004) analysis—in which numerals form a unit with the counted noun—is problematic. It fails to fully account for numeral-internal coordination and it is unclear how it could account for the semantics of ordinals.

The function of a numeral (cardinal or ordinal) designates the semantic relationship between the numeral and the counted noun. Cardinals and ordinals have a different semantics; however they seem to have identical internal structure. Based on these observations, I argued the relationship between a numeral and a counted noun is external to the internal organization of the numeral. It was proposed instead that the cardinal and ordinal semantics are mediated by an operator in the

functional head NUM. The head NUM selects the counted noun as its complement and the numeral merges as a whole into the specifier of NUM.

In my analysis, numeral-internal case patterns were accounted for via case assignment and case agreement. Because the functional head NUM in a noun phrase containing a numeral is the locus of the meaning for that noun phrase, I assumed that NUM is the head of the noun phrase. It was shown that spec-head agreement between the numeral and the NUM as well as numeral-internal case assignment determines the overall case pattern in a numeral expression.

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