

Universal Semantic Features and the Typology of Cardinal Numerals¹

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Abstract: The paper proposes a unified morpho-semantic account for the typological variation in form and meaning of cardinal numerals across languages. In particular, we investigate the morphological marking of different types of cardinals and argue that it is possible to identify cross-linguistically stable semantic ingredients, which compositionally provide the attested types of numerals. We adopt the framework of Nanosyntax (Starke 2009 et seq.) as a model of morphology which, when applied to the semantic structures we propose, delivers the relevant marking patterns. The model we develop is broadly based on the idea that the meaning components are uniformly structured across languages, and they must all be pronounced, though languages differ in how they pronounce them. All cardinals share an underlying scale of natural numbers but differ in a number of operations subsequently applied to that scale.

1. Introduction

In this paper, we investigate two different functions of cardinal numerals. We call the first function OBJECT COUNTING. It amounts to quantification over individuals denoted by the modified noun in terms of their number. For instance, the examples in (1) indicate sets of pluralities of entities whose cardinality equals 5.

- (1) a. **five** roses
b. the **five** cats

The second function will be referred to as ABSTRACT COUNTING. In this use, cardinals simply denote a number concept in an arithmetic environment (e.g., Bultinck 2005, Rothstein 2013, 2017). For example, in (2a), *five* is not used to quantify over entities; it rather designates a

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numeric value. Similarly, in (2b), the numeral denotes an abstract mathematical entity of which the property of being prime is predicated.

- (2) a. Two and **five** make seven.
b. **Five** is prime.

So far, most research has focused on the object-counting use, and the abstract-counting function remains understudied (but see Rothstein 2017, Wągiel to appear). We aim to contribute to this area of research by asking the following question: What is the relationship between object-counting and abstract-counting uses of numerals? The answer we offer is that object-counting numerals are both syntactically and semantically derived from abstract-counting numerals.

The paper is organized as follows. In Section 2, we discuss the syntactic and semantic differences between abstract counting and object counting. In Section 3, we show that the two different types of numerals also show different morphological shapes across languages. In Section 4, we provide the essentials for the compositional analysis of both functions. Section 5 will demonstrate how our system accounts for the typology of attested meaning-form correspondences. Section 6 offers a brief speculation on how gender interacts with object-counting numerals, and Section 7 concludes.

2. Object counting vs. abstract counting

The distinction between the object- and abstract-counting numerals is not merely a conceptual distinction. It is also reflected in different grammatical distribution. The differential distribution reflects the fact that the two kinds of numerals are objects of a distinct type.

Specifically, we understand number concepts to be linguistic/semantic objects corresponding to abstract numbers.² Because of this, they have different properties than pluralities of individuals (Rothstein 2017). For instance, we can attribute to number concepts special properties such as being a Fibonacci number, see (3a). (3b) shows that when number concepts are compared, the dimension of comparison is based on their relative ordering. Furthermore, as witnessed by (3c), there are special grammatical constructions calling for numeric arguments. Finally, abstract-counting numerals are compatible with arithmetical calculations such as those in (3d).

² The existence of linguistic expressions of fractions and decimals (Haida & Trinh 2019) as well as *zero* (Bylina & Nouwen 2018) suggests that not only natural numbers are represented in natural language. In this paper, however, we will focus only on cardinal numerals associated with integers.

- (3) a. **Five** is a Fibonacci number.
 b. **Five** is bigger than four.
 c. Jasna can count up to **five**.
 d. Ten divided by **five** equals two.

Let us now contrast (3) with the behavior of pluralities of individuals, which lack the properties mentioned above. The sentence (4a) is awkward, because being a Fibonacci number is not something that can be attributed to a collection of things. The truth conditions of (4b) are different than those of (3b), e.g., the sentence would not be true if one compared five pebbles with four boulders. Moreover, object-counting numeral phrases are illicit in constructions calling for numeric values, see (4c). Finally, as witnessed by the awkwardness of (4d) expressions denoting pluralities of entities are incompatible with mathematical statements.

- (4) a. #**Five** things are a Fibonacci number.
 b. #**Five** things are bigger than four things.
 c. #Jasna can count up to **five** things.
 d. #Ten things divided by **five** things equals two things.

An additional difference is that only object-counting numerals allow for modification by comparative and superlative modifiers (5a–b), while abstract-counting numerals are odd with such modifiers (6a–b). One could imagine an intended interpretation of (6a) to mean something like there is a number which is bigger than five such that it is a Fibonacci number. But such a reading is not available. Similarly, (6b) is a funny statement.

- (5) a. More than **five** cities were destroyed.
 b. At least **five** children got sick.
- (6) a. #More than **five** is a Fibonacci number.
 b. #Ten divided by at least **five** equals two.

Yet another difference concerns scalarity. It has been known for a long time that object-counting numerals give rise to scalar implicatures. For instance, (7a) gets a lower bounded construal, i.e., it is interpreted in a way that you must take at least five cards. Similarly, the

main clause in (7b) can be felicitously continued by *if not more* which has been standardly assumed to be the evidence for the lower bound inference (Horn 1972).

- (7) a. You must take **five** cards.
b. John took **five** cards, if not more.

However, abstract-counting numerals do not give rise to scalar implicatures and always get bilaterally bounded interpretations (cf. Sadock 1984, Horn 1992, Bultinck 2002). For instance, (8a) cannot be interpreted in a way that in order to get ten you must multiply two by at least five. That seems strange, and false if this interpretation is forced. Similarly, (8b) cannot be felicitously continued by the *if not more* clause.

- (8) a. You must multiply two by **five** to get ten.
b. Two multiplied by **five** equals ten, #if not more.

The distinction is further corroborated in languages with gender marking. Here abstract-counting cardinals often display different gender than object-counting forms (cf. Fassi Fehri 2018, Wągiel to appear). For instance, the Polish numeral *pięć* ('five') triggers neuter agreement on the demonstrative in its abstract-counting use, see (9a). When used as an object-counting form, it agrees with the modified noun, and consequently triggers the non-virile plural in (9b).³

- (9) a. **To pięć** zapisano cyfrą arabską, a tamto rzymską. Polish
this.N five.N was.written cipher.INS Arabic.INS and that.N Roman.INS
'This five was written with an Arabic numeral, whereas that one with a Roman one.'
b. **Te pięć** jabłek leży na stole, a tamte na podłodze.
these.NV five.NV apples.NV.GEN lies on table.LOC and those.NV on floor.LOC
'These five apples are lying on the table whereas those ones on the floor.'

With the distinction between the two cardinals in place, let us now focus on the cross-linguistic variation in how the numeral itself reflects (or fails to reflect) this difference morphologically.

³ In the paper, we will use the following abbreviations: N – neuter gender, F – feminine, M – masculine, NV – non-virile gender, NOM – nominative case, GEN – genitive, ACC – accusative, DAT – instrumental, INS – instrumental, LOC – locative, TOP – topic marker, COP – copula, CL – classifier and NBR – abstract number marker.

3. Abstract-counting and object-counting numerals across languages

It has been observed in the literature that abstract- and object-counting numerals may have a different form (cf. Hurford 1998, 2001). On the basis of the morphological relation between the numerals, we distinguish several patterns. We introduce them below.

3.1. The asymmetric pattern

In a pattern we will call asymmetric, the object-counting numeral contains the abstract-counting numeral as a proper subpart. This pattern is typically found in obligatory classifier languages. For instance, in Japanese (Sudo 2016), the object counting numeral contains the morpheme *go* ('five'), and an additional morpheme, e.g., *rin* or *ko*, usually referred to as a classifier, see (10b).⁴ Bare cardinals are ungrammatical as nominal modifiers, see (10a).

- (10) a. ***go**-no hana Japanese
five-GEN flower
b. **go-rin**-no hana
five-CL-GEN flower
'five flowers'

However, in an abstract-counting environment, e.g., an arithmetical statement such as (11a), a numeral cannot occur with a classifier. Though *go* is a general classifier and could be used to indicate any type of inanimate entity, the sentence in (11b) is odd.⁵

- (11) a. juu waru **go**-wa ni-da. Japanese
ten divide.by five-TOP two-COP
'Ten divided by five is two.'
b. #juu-ko waru **go-ko**-wa ni-ko-da.
ten-CL divide.by five-CL-TOP two-CL-COP

Among the languages which distinguish between object- and abstract-counting, such an asymmetry is relatively frequent. For instance, the same asymmetry is also attested in Mandarin.

⁴ In Japanese, the morpheme *rin* is a classifier used for counting flowers, whereas *ko* is a general classifier for counting inanimate entities.

⁵ We would like to thank Yasu Sudo and Kazuko Yatsushiro for the discussion of the Japanese data and as well as their judgments concerning (11).

Specifically, in an object-counting environment such as (12), numerals require classifiers. In contexts unambiguously calling for numeric arguments, classifiers are odd, see (13).⁶

- (12) a. ***wǔ** shū Mandarin
 five book
 b. **wǔ-běn** shū
 five-CL book
 ‘five books’

- (13) a. shí chùyǐ **wǔ** shì èr. Mandarin
 ten divide.by five COP two
 ‘Ten divided by five is two.’
 b. #shí-gè chùyǐ **wǔ-gè** shì èr-gè.
 ten-CL divide.by five-CL COP two-CL

Similar contrasts are attested in other obligatory classifier languages we have looked at such as Vietnamese and Thai.⁷ We interpret these facts as suggesting that the abstract-counting function is basic, and the object-counting function is derived from it (both morphologically and semantically).

3.2. *Symmetric numerals*

In a number of languages, however, we observe no asymmetry between the numerals, i.e., the two forms are identical. For instance, in English both functions are expressed by the same formal exponent, see (14). We will call cardinals displaying such behavior SYMMETRIC numerals.

- (14) a. **five** roses
 b. Ten divided by **five** is two.

⁶ We would like to thank Chang Liu for the discussion of the Mandarin data and his judgments concerning (13).

⁷ We would like to thank Tue Trinh and Pittayawat Pittayaporn for their judgments concerning Vietnamese and Thai, respectively.

We interpret such forms as ambiguous. In one use, they are semantically equivalent to the Japanese classifier construction *go-ko*, in another to bare *go*. In the former use, the bare numeral itself incorporates a classifier semantics (Krifka 1995).

It is important to note that these patterns are not properties of a language as a whole, but rather of a particular numeral. This is required by languages such as Chol and Mi'gmaq, where some numerals show the asymmetric pattern, while other numerals exhibit the symmetric one (Bale & Coon 2014).

3.3. Idiosyncratic numerals

A separate pattern is represented by what we call IDIOSYNCRATIC numerals. A language has idiosyncratic numerals if the two functions we are interested in here are expressed by two different morphologically simplex forms, i.e., the relation between the numerals is suppletive.

An example is provided by Maltese. Maltese has two distinct, morphologically unrelated forms for the number 2, specifically *żewġ* and *tnejn* (both 'two'). The form *żewġ* is an object-counting form, see (15a) (from A. Borg 1974). *Tnejn* is an abstract-counting numeral used in mathematical statements, see (16a) (from A. J. Borg 1987). Importantly, *tnejn* cannot be used as a nominal modifier, see (15b), and *żewġ* is incompatible with environments calling for numeric arguments (16b).⁸

- (15) a. **żewġ** nisa Maltese
 two₁ women
 'two women'
 b. ***tnejn** nisa
 two₂ women

- (16) a. Tnejn u **tnejn** jagħmlu erbgħa. Maltese
 two₁ and two₁ they-make four
 'Two and two make four.'
 b. *Żewġ u **żewġ** jagħmlu erbgħa.
 two₂ and two₂ they-make four

⁸ We would like to thank Albert J. Borg for the discussion of the Maltese data as well as his judgments on (16).

We will analyze the form *żewg* as a simplex form that corresponds to the analytic classifier construction, e.g., *ni-ko* (‘two-CL’) in Japanese. *Tnejn* then corresponds to the bare numeral root in an obligatory classifier language, e.g. *ni* (‘two’).

Though rare, the idiosyncratic pattern is not limited to Maltese. Additional examples include at least the Ojibwe (Algonquian) *ninkotw ~ pešikw* (both ‘one’) (Denney & Odjig 1973), Palaung (Austroasiatic) *ū ~ hleh* (both ‘one’) (Greenberg 1978), the Iḃani (Eastern Ijaw) numerals *gbeṛe ~ ngiṛe* (both ‘one’) and *oyi ~ atie* (both ‘ten’) (Obikudo 2016).⁹

3.4. Inverse numerals

The final pattern is one where the abstract-counting numeral properly contains the form of the object-counting numeral. This pattern is the inverse of the asymmetric pattern and we therefore call it the INVERSE pattern. For instance, in the case of the German *eins ~ ein* (both ‘one’), abstract counting is expressed by a morphologically more complex form (*eins*) than object counting (Hurford 1998, 2001). As demonstrated by the contrasts in (17) and (18), *eins* cannot be used as a nominal modifier while *ein* is incompatible with arithmetical environments.¹⁰

- (17) a. **ein** Apfel German
 one apple
 ‘one apple’
 b. ***ein-s** Apfel
 one-NBR apple

- (18) a. Zehn geteilt durch **ein-s** ist gleich zehn. German
 ten divided by one-NBR is equal ten
 ‘Ten divided by one equals ten.’
 b. *Zehn geteilt durch **ein** ist zehn.
 ten divided by one is ten

⁹ Note, however, that we did not have an opportunity to thoroughly test the reported alternations as we did in the Maltese case, and thus we rely here on the authors’ comments.

¹⁰ We would like to thank Nina Haslinger for her judgments and comments concerning German. Notice also that the ill-formedness of (18b) has nothing to do with the accusative case assigned by the preposition *durch* (‘by’) since the ungrammaticality of (i) with the accusative masculine form *einen* (‘one’) confirms the contrast.

- (i) *Zehn geteilt durch **einen** ist gleich zehn. German
 ten divided by one.M.ACC is equal ten

The inverse pattern seemingly requires the opposite semantic derivation compared to the object-counting function. In particular, it seems that here the abstract-counting function has some extra meaning, corresponding to the additional morpheme (the suffix *-s* in German). However, admitting this would jeopardize a morpho-semantic explanation of the widespread asymmetry illustrated in (10)–(13) as well as any unified typology of cardinal numerals. We will therefore propose an alternative derivation of this pattern.

Other cases of inverse numerals reported in the literature include the Hungarian *kettő ~ két* (both ‘two’) and the Eastern Basque *biga ~ bi* (both ‘two’) (Hurford 1998, 2001). However, our inquiry reveals that most probably the distinction has not been described properly, because the marked and unmarked forms introduced above are not in complementary distribution. For instance, in Hungarian, both *kettő* and *két* can be used as nominal modifiers, see (19), but only *kettő* can appear in mathematical contexts, as demonstrated in (20).¹¹

- (19) **ket-(tő)** macska Hungarian
 two-NBR cat
 ‘two cats’

- (20) Egy meg egy az **ket-*(tő)**. Hungarian
 one plus one is two-NBR
 ‘One plus one equals two.’

Though space prohibits to investigate cases such as Hungarian 2 in detail, we report that to the best of our knowledge genuine instances of the inverse marking pattern are scarce. What we need to capture then is the fact that alternations such as *eins ~ ein* in German exist, but at the same time that they are very rare.

3.5. Interaction with gender

The final piece of evidence comes from languages that mark gender on cardinal numerals. It has been observed in the literature that there is a non-trivial interaction between grammatical gender and quantification (Arsenijević 2016, Fassi Fehri 2018, Wągiel to appear) and the data to be discussed seem to further corroborate this claim. As already signaled in Section 2, gender marking on cardinals is often correlated with the abstract/object counting distinction. For

¹¹ We would like to thank Flóra Lili Donáti and Maia Duguine for being our informants on Hungarian and Eastern Basque, respectively.

instance, let us consider the non-virile/virile distinction in Bulgarian. As indicated in (21), Bulgarian numerals 2–10 need to agree with the noun, and thus, e.g., the unmarked non-virile form *pet* (‘five’) is incompatible with virile NPs, whereas the marked virile form *petima* (‘five’) cannot co-occur with non-virile NPs (Cinque & Krapova 2007). Interestingly, only the unmarked form *pet* can appear in a context calling for a number concept, see (22).¹²

- (21) a. **pet-(*ima)** ženi Bulgarian
 five-V women.NV
 ‘five women’
 b. **pet-?(ima)** mâže
 five-V men.V
 ‘five men’

- (22) Deset deleno na **pet-(*ima)** e dva. Bulgarian
 ten divided on five-v is two
 ‘Ten divided by two is five.’

The contrast in (22) is an instance of the asymmetric pattern arising as a result of the interaction with grammatical gender. A similar distinction is also attested in other Slavic languages that mark gender on cardinals, e.g., Polish and Slovak (Wągiel to appear).

Interestingly, also an inverse pattern can emerge as a consequence of gender marking. As an example, consider Standard Arabic. Numerals in this language are known for the gender mismatch between cardinals 3–10 and modified nouns (‘gender polarity’). As demonstrated in (23a), when the numeral combines with a feminine noun, it has the unmarked masculine form. But when combined with a masculine noun, the numeral requires the feminine suffix *-at*, see (23b). Crucially, only the feminine form, i.e., *talaat-at* (‘three’) in (24a), can be used as an abstract-counting expression (Fassi Fehri 2018). As a consequence, the more marked form is used as an abstract-counting expression, similar to the pattern observed for German 1 in (18).

- (23) a. **talaat-(*at)-u** banaat-in Standard Arabic
 three-F-NOM girls.F-GEN
 ‘three girls’

¹² We would like to thank Marina Pantcheva for her judgments and comments concerning Bulgarian.

- b. **talaat-*(at)-u** ʔawlaad-in
 three-F-NOM boys.M-GEN
 ‘three boys’

- (24) a. **talaat-at-un** t-usawii ʔitnayni zaʔid waahid. Standard Arabic
 three-F-NOM F-equals two plus one
 ‘Three equals two plus one.’
 a. ***talaat-un** y-usawii ʔitnayni zaʔid waahid.
 three-NOM M-equals two plus one

As one can see, the overall picture is quite complex. Hence, before we move on to proposing an analysis that attempts to explain how all the patterns are derived, let us summarize the data.

3.6. Data summary

In this section, we have examined four patterns of morphological marking regarding the abstract/object counting distinction summarized in Table 1.

TYPE	LANGUAGE	NUMBER	ABSTRACT	OBJECT
SYMMETRIC	English	5	<i>five</i>	<i>five</i>
IDIOSYNCRATIC	Maltese	2	<i>tnejn</i>	<i>żewġ</i>
ASYMMETRIC	Japanese	5	<i>go</i>	<i>go-ko</i>
INVERSE	German	1	<i>ein-s</i>	<i>ein</i>

Table 1. Morphological marking patterns

Symmetric numerals do not distinguish between the abstract- and the object-counting form. Idiosyncratic numerals have a suppletive form for each of the two functions. The asymmetric pattern arises when object-counting cardinals contain the abstract-counting form. And finally, in inverse numerals, the abstract-counting form contains the object-counting form. Importantly, the patterns are numeral-specific rather than language-specific, since in one language there can be more than one type of numerals. Finally, the symmetric and inverse pattern can emerge as a result of gender marking on the cardinal.

In the next section, we put forth a set of cross-linguistically stable semantic components that the numerals are made out of. This will allow us to explain the abstract/object counting

distinction examined in Section 2. The very same components feed into a unified morpho-semantic system to account for the typological variation discussed in this section.

4. Universal semantic features

4.1. *Classifiers and nominal denotations*

In the semantic literature, it is commonly assumed that the distinction between obligatory classifier languages such as Mandarin and non-classifier languages such as English is due to a difference in the semantics of nouns (e.g., Chierchia 1998, 2010, Borer 2005, Rothstein 2010, Li 2011, Scontras 2013). According to this standard approach, all nouns in classifier languages are mass-like in the sense that they have uncountable denotations. Thus, in order to combine an NP with a numeral, a classifier is required. That is because classifiers compensate a semantic deficit of nouns by turning uncountable denotations into countable ones.

Though the received view is appealing, there are reasons to believe that it is in fact incorrect. One of the main counterarguments is based on the fact that in obligatory classifier languages, certain counting modifiers, e.g., Japanese *tasuu* ('numerous') and *nan-zen-toiu* ('thousands'), appear without classifiers, and they only combine with NPs denoting countable entities, e.g., *hana* ('flower') as opposed to *ase* ('sweat') (Sudo 2016). Another problem for the standard approach concerns languages such as Chol and Mi'gmaq, where some cardinals require classifiers, whereas others do not (Bale & Coon 2014).

Therefore, we adopt an alternative explanation of the role of classifiers in obligatory classifier languages. According to this alternative, it is not the semantics of nouns what differentiates the two types of languages but rather it is the semantics of numerals. In particular, in obligatory classifier languages, classifiers are required to compensate semantic deficits of cardinals. These (according to the hypothesis) lack the semantics that would enable them to function as counting devices, i.e., as modifiers equipped with an operation allowing for numeric quantification (Krifka 1995, Bale & Coon 2014, Sudo 2016). In this paper, we will embrace this alternative way of thinking about numerals and classifiers.

4.2. *Semantic components*

In order to account for the morphological patterns discussed in the previous section, we propose the ingredients in (25) as the universal inventory of components that numerals are built out of.

In particular, we postulate three syntactic heads SCALE, NUM (for ‘number’) and CL (for ‘classifier’), accompanied with the standard function application operation.¹³

- (25) a. $\llbracket \text{SCALE} \rrbracket_{\langle n, t \rangle} = \lambda m_n [m \geq n]$
 b. $\llbracket \text{NUM} \rrbracket_{\langle \langle n, t \rangle, n \rangle} = \lambda P_{\langle n, t \rangle} [\text{MIN}(P)]$
 c. $\llbracket \text{CL} \rrbracket_{\langle n, \langle \langle e, t \rangle, \langle e, t \rangle \rangle \rangle} = \lambda n_n \lambda P_{\langle e, t \rangle} \lambda x_e [*P(x) \wedge \#(P)(x) = n]$

As indicated in (25a), SCALE is a lower bounded set, i.e., a set of natural numbers in a particular interval $[n, \infty)$ (type $\langle n, t \rangle$). We assume that the value of the lower bound is lexically encoded and depending on a numeral it could be, e.g., $[4, \infty)$ or $[5, \infty)$ etc. Moreover, we posit that SCALE is a core feature underlying the semantics of all number words including cardinal numerals as well as ordinals, multiplicatives, fractions and other complex numerical expressions.

The NUM head is a function from intervals to numbers, see (25b). It takes a set of integers and introduces a minimization operation MIN which yields the smallest number from that set. For instance, if applied to the interval $[4, \infty)$, it will return 4 whereas when applied to $[5, \infty)$, it will yield 5 etc. Hence, the role of NUM is to forge a proper name of an abstract mathematical entity, i.e., an expression of a primitive type n .¹⁴

Finally, CL is a function from an integer to a counting device (type $\langle n, \langle \langle e, t \rangle, \langle e, t \rangle \rangle \rangle$), see (25c). Specifically, it takes a number and shifts it to a predicate modifier equipped with the pluralization operation $*$ (Link 1983) and the measure function $\#(P)$ (Krifka 1989).¹⁵ While $*$ adds to the denotation of a predicate all the sums that can be formed from the atomic elements of a singular denotation, $\#(P)$ is an extensive measure function which maps a plurality of entities onto a numeric value corresponding to the number of entities making up that plurality. It is additive, monotonic and has the Archimedean property. The goal of the CL head is thus to form an expression that can be used for numeric quantification over actual objects.¹⁶

¹³ The chosen labels are intended to evoke the relevant associations, e.g., NUM – the notion of a number concept. Notice, however, that we do not claim that, e.g., the semantics of CL is all there is to the meaning of classifiers in classifier languages. What we focus on here is strictly restricted to the abstract/object counting distinction.

¹⁴ The fact that abstract-counting numerals are proper names is quite likely reflected in their nominal nature (see Ionin & Matushansky 2018).

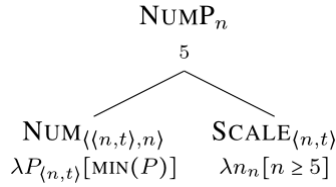
¹⁵ Actually, Krifka uses the NU (for ‘natural unit’) operation. We depart from the original notation here since due to independent reasons, we do not postulate that numeric quantification resorts to the notion of a natural unit (for some discussion, see Wągiel 2018).

¹⁶ Though we assume CL to be a function from number concepts to predicate modifiers, nothing prevents it to be a shift from integers to some other type, e.g., cardinal properties or determiners. In principle, the proposed system is compatible with other theories of numerals as long as it is possible to relate a type for the object-counting function with the primitive type n .

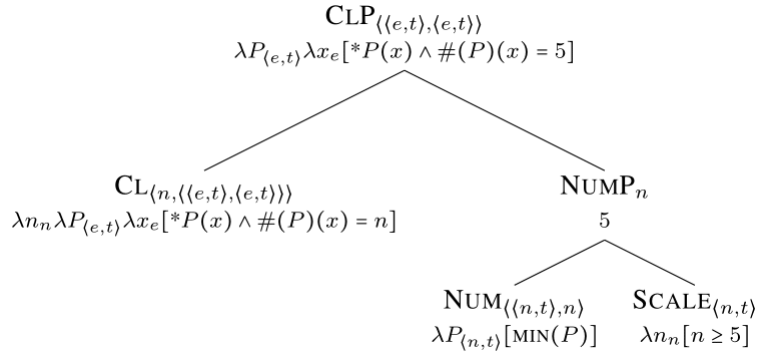
4.3. Composition

In order to combine the meanings of the heads introduced above, we assume standard function application. Combining the ingredients in (18) in a compositional fashion leads to the structures in (26)–(27).

(26) Abstract counting



(27) Object counting



The tree in (26) represents the structure and meaning of an abstract-counting numeral, referring to the number 5. The tree shows that due to the application of MIN to SCALE, the interval $[5, \infty)$ is turned into the integer 5. The resulting expression is thus of the type n , designating a number concept. NUMP is thus a proper name of an arithmetical entity. Properties such as *be a prime* or *be a Fibonacci number*, which we assume to be of type $\langle n, t \rangle$, can be predicated of this object.

The tree in (27) shows how the meaning of a corresponding object-counting numeral is derived. The CL phrase as a whole is interpreted as a predicate modifier. After the number slot of the CL head in (27) is saturated by 5, we obtain an expression that applies to a predicate and yields a set of pluralities of entities that have the relevant property and whose cardinality equals 5. Hence, when CLP is combined with a countable NP, we obtain a denotation such as the one in (28), i.e., a set of pluralities of roses such that each plurality in that set consists of 5 roses.

$$(28) \quad \llbracket \text{five roses} \rrbracket = \lambda x_e [* \text{ROSE}(x) \wedge \#(\text{ROSE})(x) = 5]$$

In sum, this proposal correctly derives the different properties of abstract- and object-counting numerals. However, it apparently gives rise to redundancy. In particular, it may seem equally justified to postulate only NUM (denoting numbers) and CL (turning numbers to counting devices) and do away with the SCALE part of the structure. The reasons why we need SCALE will become fully clear in Section 5 where we demonstrate how our system derives the

morphological patterns investigated above and inverse numerals in particular. But before we get there, let us consider some independent evidence for proposing SCALE.

4.4. Motivating SCALE

The first piece of evidence comes from the fact that abstract-counting numerals can be morphologically complex. Consider, for instance, the data from the Oceanic language Vurës (Vanuatu) given in Table 2. The table shows that cardinals 1–9 include an invariant prefix *ni-* attached to various numeral roots (Malau 2016, p.c.). The reason why *ni-* must be separated from the root and acknowledged as a separate morpheme is the fact that ordinals and multiplicatives lack this prefix. Morphologically, they are not derived from cardinals but rather from the root of the cardinal numeral. Under the hypothesis that morphemes express meaning, this fact entails that cardinal numerals have at least two components of meaning. Specifically, we understand the bound morpheme *ni-* to be the exponent of NUM in abstract-counting contexts (and a portmanteau for NUM and CL in object-counting environments). Individual roots simply lexicalize different SCALE heads.

NUMBER	CARDINAL	ORDINAL	MULTIPLICATIVE
2	<i>ni-rō</i>	<i>rō-ne</i>	<i>vagō-rō</i>
3	<i>ni-tōl</i>	<i>tōl-ne</i>	<i>vag-tōl</i>
4	<i>ni-vet</i>	<i>vet-ne</i>	<i>vag-vet</i>
5	<i>ni-tevelēm</i>	<i>tevelēm-ne</i>	<i>vag-tevelēm</i>
6	<i>ni-levetē</i>	<i>levetē-ne</i>	<i>vag-levetē</i>

Table 2. Vurës numerals

The morphological make-up of numerals such as the one discussed above is not a Vurës peculiarity. Similar patterns are common in Sino-Tibetan languages and have been observed, e.g., in Lushai (Mizo), Mishmi (Digaro) and Newar (Newaric) to name just a few languages (see Matisoff 1995 and the references therein).¹⁷

Morphologically complex abstract-counting numerals are found also closer to home, namely in Slavic.¹⁸ The Czech numerals *pět* (‘five’), *devět* (‘nine’) and *deset* (‘ten’) all share

¹⁷ Such patterns have been traditionally described as ‘affix runs’ in Sino-Tibetan linguistics.

¹⁸ In fact, it has already been argued that Slavic cardinals are not simplex expressions but rather that they are compositional (Wągiel 2015, to appear). Here, we make an even stronger claim.

the same element *-ět/-et* (a difference which amounts to orthography). This fact alone could of course be accidental and does not immediately lead to the conclusion that the shared coda of the numerals corresponds to an independent morpheme. However, as indicated in Table 3, in ordinals and complex cardinals, *ě/e* alternates with *á/a*. This vocalic alternation is not a productive part of the Czech phonology and must be treated as suppletive. Thus, taking *-et* and *-át* to be independent morphemes allows us to have a single suppletive element (which captures the regularity of the alternation across the three numerals). In the absence of decomposition, each of the relevant numerals would have to be suppletive individually and the common profile of the alternation would be lost. This suggests that Czech *pět*, *devět* and *deset* are morphologically complex. We hypothesize that similar to what we have seen in Vurës the elements *p-*, *dev-* and *des-* lexicalize different SCALE heads, whereas *-ět/-et* is a bound suffix expressing NUM or NUM and CL in abstract- and object-counting contexts, respectively.

NUMBER	CARDINAL	ORDINAL	COMPLEX CARDINAL
7	<i>sedm</i>	<i>sedm-ý</i>	<i>sedm-desát</i>
8	<i>osm</i>	<i>osm-ý</i>	<i>osm-desát</i>
5	<i>p-ět</i>	<i>p-át-ý</i>	<i>p-a-desát</i>
9	<i>dev-ět</i>	<i>dev-át-ý</i>	<i>dev-a-desát</i>
10	<i>des-et</i>	<i>des-át-ý</i>	—

Table 3. Czech numerals

Morphologically complex numerals tell us that there must be two meaning components in abstract-counting cardinals (minimally as a possibility). This alone does not tell us what exactly these meaning components are. The reason for identifying SCALE as one of the relevant ingredients comes from scalar implicatures. Though many pages have been written on this topic, so far the mainstream research has been almost exclusively focused on cardinal numerals. However, we observe that scalar inferences are not limited to cardinals and arise also in the presence of a number of different types of derived numerical expressions including, e.g., multiplicatives, multipliers and ordinals. Consider the sentences in (29). All of those examples have a lower-bounded interpretation.

- (29) a. Jasna must win the championship **twice** to be inducted into the hall of fame.
b. Jasna must be a **two-time** champion to be inducted into the hall of fame.

- c. Jasna must be **two times** taller than now to become a professional basketball player.
- d. Jasna must ensure a **twofold** increase in the price of oil to become a billionaire.
- e. Jasna must order a **double** portion to get a free drink.
- f. Jasna must finish **second** to get a prize.

For instance, the most natural way to understand (29a) is that Jasna must win the championship at least two times to get into the hall of fame. Similarly, the adjective *two-time* in (29b) gives rise to the at least reading, i.e., being a three-time champion would also help Jasna to be recognized as a legendary player. The same applies to modified comparatives since (29c) means that little Jasna must be at least twice as tall as now to pursue a career in basketball. Moreover, numerical expressions such as *twofold* and multipliers like *double* in (29d) and (29e), respectively, behave on a par with cardinals.¹⁹ Specifically, a threefold increase in the price of oil would also result in Jasna becoming a billionaire. Similarly, ordering a triple portion would grant her a free drink as well. Finally, ordinals also give rise to reversed scalar implicatures since on the most natural interpretation of (29f), finishing first would also result in getting a prize.²⁰

To our knowledge, the effects described above have not been observed so far in the literature. What is important, however, is that this novel observation seems to present a challenge for approaches explaining the unilaterally bounded interpretations only in terms of weak truth conditions of existential quantification. It is unclear how to account for the data in (29) by simply postulating existential closure. Though we can imagine that this should work for the sentences where arguably quantification over events is involved as in (29a), we find the other examples in (29) to be much more mysterious. Hence, we hypothesize that at some level lower bounded semantics is a common part of all the complex numerical expressions discussed above. Possibly, they all share the same SCALE head or at least something similar to it.

Given both the semantic evidence from scalar implicatures and the existence of morphologically complex abstract-counting cardinals, we conclude that postulating SCALE and NUM is not superfluous as it might have initially seemed. The proposal is motivated by empirical facts that would be hard to explain if abstract-counting numerals simply corresponded

¹⁹ In English, multipliers such as *double* and *triple* are Latin borrowings. However, in many languages, e.g., in Slavic and Baltic, they are derived from numeral roots shared with cardinal numerals (Wągiel 2018, to appear). Similarly, English *second* is a suppletive form but this is just a fact to notice about this particular English ordinal.

²⁰ Due to space limitations, we do not discuss here how such inferences are derived. We only report that they exist.

to a number denoting head. In the next section, we will discuss how the morphological patterns examined in Section 3 relate to the postulated semantic components.

5. Deriving the shape of cardinal numerals

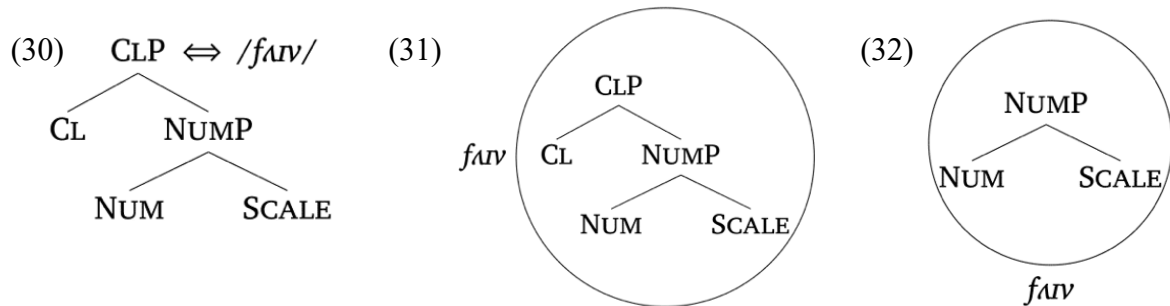
We now proceed to show how the shapes of the various types of numerals are derived. In doing so, we adopt one of the basic insights of current theories of morphology, namely late insertion. The idea is that the actual exponents of meaning, e.g., /fʌrv/, are not present in the syntactic/semantic component at all. What is present in syntax are only the abstract (language-invariant) features, e.g., SCALE, NUM and CL, which the syntactic component assembles into structures like those in (26) and (27). The actual exponents are inserted only after syntax. Late insertion is the core of current approaches such as Distributed Morphology (Halle & Marantz 1993) and Nanosyntax (Starke 2009).

The rules that relate exponents to features are the lexical items of a language. Lexical items are language-specific objects that pair a well-formed syntactic structure S , e.g., [NUM SCALE], a well-formed phonological structure P , e.g., /fʌrv/, and a conceptual meaning C (if any). From the perspective of string generation, lexical items are read as instructions of the sort: if syntax constructs the structure S , pronounce/realize S by the exponent P .

In what follows, we will describe (though not motivate) a model of spellout that uses lexical entries in order to translate the universal structures of numerals given in (26) and (27) onto language-particular outputs, yielding the full typology of numeral types introduced in Section 3. In doing so, we will rely on the framework of Nanosyntax (Starke 2009, Caha 2009), and in particular on the version of the theory that includes spellout driven movement (Starke 2018, Baunaz & Lander 2018, Caha et al. 2019). We think that a similar goal can be achieved using the framework of Distributed Morphology, but we will not show this for reasons of space.

5.1. Symmetric numerals

Let us start from the fact that a numeral such as /fʌrv/ can function as an object-counting numeral. In Nanosyntax, this means that this numeral is able to lexicalize all the three meaning components of the structure given in (27). The way this is technically achieved is by assigning this numeral the lexical entry as in (30). The lexical entry pairs a well-formed syntactic structure with phonology. When syntax builds a structure corresponding to the numeral (as in (27)), the lexical item (30) can be used to pronounce this structure, because it is identical to it. This is indicated by the circle around the relevant structure in (31), i.e., the structure as a whole (specifically its top-most phrasal node) is pronounced by /fʌrv/.



Suppose now that syntax builds only the structure for the abstract-counting numeral as in (26). In Nanosyntax, this structure can be also lexicalized by the lexical entry in (30), because it is contained inside the lexical entry. This is indicated in (32), where the relevant structure is circled, indicating that $/f\lambda v/$ can be inserted here. As a result, when a numeral has a lexical entry such as (30), it is ambiguous between the two different uses.

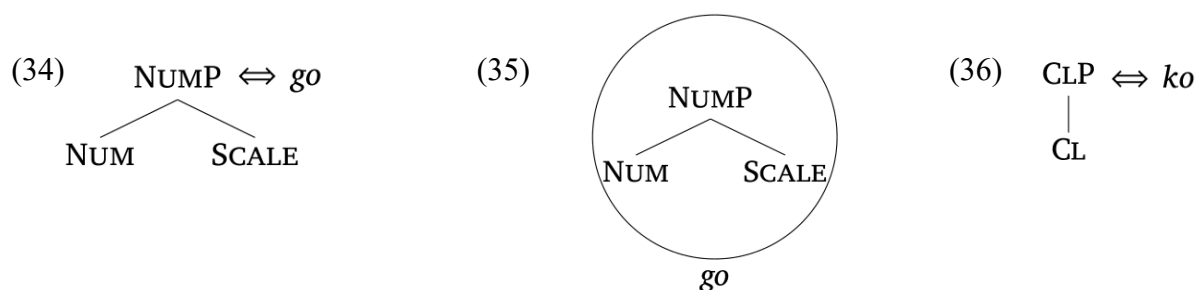
This type of ambiguity arises as a consequence of one of the core properties of late insertion models, which is that lexical entries are not tailor-made for one specific use. For instance, in Distributed Morphology, this is encoded by one of the core principles, the so-called Subset Principle. In Nanosyntax, the relevant principle works slightly differently, and it is called the Superset Principle, see (33). This principle achieves that a lexical entry can be used to pronounce a particular structure iff it contains that structure as a sub-part (proper or not). Since both trees in (31) and (32) are contained in (30), the numeral $/f\lambda v/$ is ambiguous.

(33) *The Superset Principle* (Starke 2009):

A lexically stored tree matches a syntactic node iff the lexically stored tree contains the syntactic node.

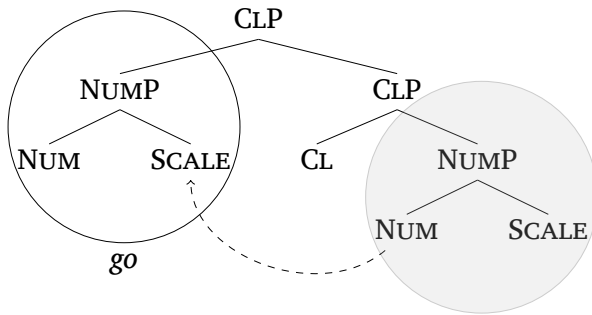
5.2. Asymmetric numerals

Let us now turn to asymmetric numerals. These arise when the lexical entry of the numeral only contains the NUM and SCALE components, see (34). Such an exponent can lexicalize the structure of an abstract-counting numeral, see (35). However, it cannot lexicalize the object counting structure, because it does not contain it, specifically it lacks the feature CL.

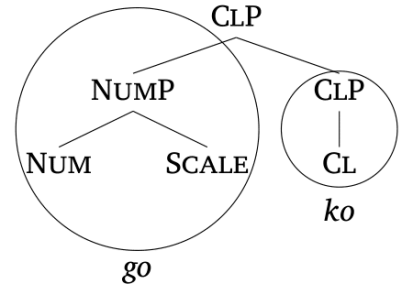


In such numerals, CL needs to be spelled out by a separate entry, like the one in (36). In order for this entry to apply at the CLP node, NUMP is displaced from its base-position due to movement, see (37). The lower copy of the moved element, i.e., the trace, is shaded. In Nanosyntax, the movement in (37) is driven by the need to lexicalize the phrasal CLP node by the lexical entry (36). In particular, before the movement, the lexical item (36) does not match the lower CLP in (37), because it does not contain this phrase.

(37)



(38)



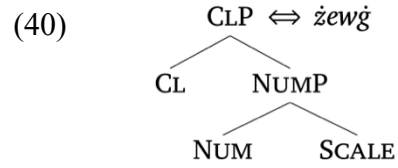
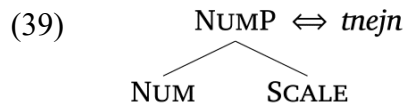
After the movement (and ignoring the trace), it does so, as shown in (38), where the classifier *ko* is inserted at the relevant node, as indicated by the circle. We leave it unexplored here as to how precisely this movement is triggered, but see, e.g., Baunaz & Lander (2018), Caha et al. (2019), Vanden Wyngaerd et al. (2019) for detailed explanations.

To sum up, we have shown that when the numeral's root is specified only for SCALE and NUM, the root will appear bare only in the abstract-counting function given in (35). In the object-counting function in (38), CL must be spelled out by an additional element, i.e., the classifier.

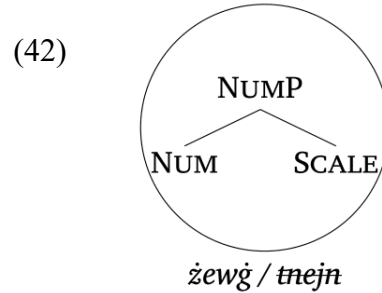
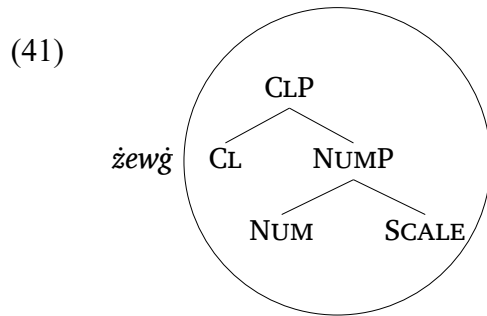
Note that there is no requirement that all numerals in a language must have the same lexical entry. As a consequence, a system of this type allows for the simultaneous presence of multiple kinds of numerals within a single grammar. This is required to capture the fact reported in Section 3.2 that in languages such as Chol and Mi'gmaq both symmetric and asymmetric numerals are attested (Bale & Coon 2014).

5.3 Idiosyncratic numerals

Let us now consider idiosyncratic numerals. Recall that such numerals have a dedicated non-decomposable form for each of the two functions. An example discussed in Section 3.3 was the Maltese numeral 2. Such a behavior can be modeled by postulating two suppletive lexical entries for idiosyncratic numerals. One entry introduces the root found in the abstract-counting function, see (39). The second entry introduces the root for the abstract-counting numeral (40).

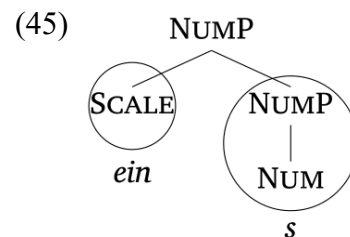
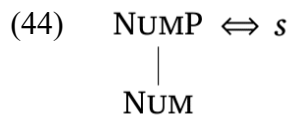


When syntax produces the object-counting structure, only *żewg* ('two') can be inserted, because *tnejn* ('two') does not contain this structure, see (41). However, in the abstract-counting structure, both numerals are candidates for insertion, because they both contain the relevant structure. As a result, a competition arises with the result that the more specific item is chosen, see (42). The competition is resolved by the so-called Elsewhere Condition (Kiparsky 1973), again a standard ingredient of all late-insertion theories.

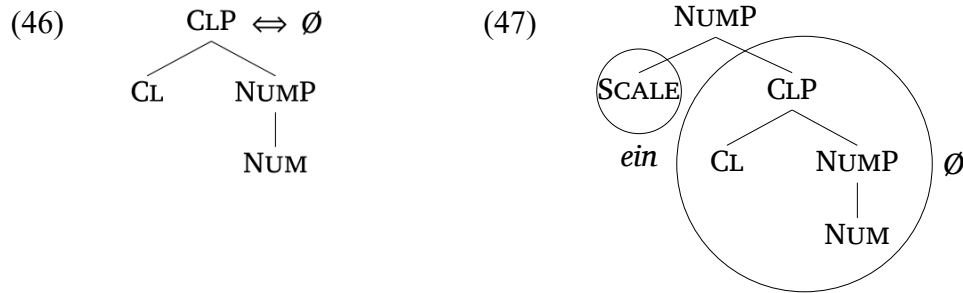


5.4 Inverse numerals

Finally, let us now turn to the treatment of inverse numerals such as German 1. We start from the fact that the abstract-counting numeral *ein-s* is morphologically complex. This entails that the root *ein* cannot, on its own, spell out the full abstract-counting structure. We, therefore, assign to it the lexical entry in (43), which says that this numeral can only spell out the SCALE node. As a consequence, the numeral needs to combine with an additional morpheme in order to express all the components of the abstract-counting structure, NUM in particular. Hence, we specify the morpheme *-s* for exactly this function, as provided in (44). Thus, the abstract-counting structure looks as in (45), where the SCALE feature has moved from its base position across NUM, similarly to (37).



With this analysis in place, what can we say about the object-counting use of *ein* in German? Starting from the observation that the root of *ein* (recall (43)) cannot pronounce the full structure of the object-counting numeral, we must draw the conclusion that the remaining features are spelled out by a different morpheme. Since there is no overt morpheme visible in the object-counting *ein*, we postulate a zero morpheme: *ein-Ø*. The lexical entry of the zero marker is in (46) and the full structure of the object-counting numeral is in (47). In this structure, the SCALE component moves out of the NUMP, which is spelled out by the relevant \emptyset marker.



This analysis is supported on paradigmatic grounds. Specifically, the German object-counting numeral *ein* has a full case/number paradigm illustrated in Table 4. Here, only some cells of the paradigm show the problematic inverse pattern, while other cells have an overt affix. The idea of a zero marker is thus supported on analogy with the other paradigm cells.

	MASCULINE	NEUTER	FEMININE
NOM	<i>ein-Ø</i>	<i>ein-Ø</i>	<i>ein-e</i>
ACC	<i>ein-en</i>	<i>ein-Ø</i>	<i>ein-e</i>
GEN	<i>ein-es</i>	<i>ein-es</i>	<i>ein-er</i>
DAT	<i>ein-em</i>	<i>ein-em</i>	<i>ein-er</i>

Table 4. The inflection of the German indefinite article/numeral 1

As one can see, the developed approach offers a significant explanatory power. However, before we move on to a more detailed discussion of the role of gender in abstract/object counting, let us summarize the meaning/form correspondences derived by the proposed system.

5.5 Summary

Our account of the morphological patterns described in Section 3 is summarized in the first four lines of Table 5.

ABSTRACT COUNTING			OBJECT COUNTING		
SCALE	NUM		SCALE	NUM	CL
	<i>five</i>	English 5		<i>five</i>	
	<i>tnejn</i>	Maltese 2		<i>zewġ</i>	
	<i>go</i>	Japanese 5		<i>go</i>	<i>ko</i>
<i>ein</i>	<i>s</i>	German 1	<i>ein</i>	Ø	
X	α	PRED ₁	X	β	
X	α	PRED ₂	X	α	β

Table 5. Meaning/form correspondences

The left-hand column of the table highlights our proposal for abstract-counting numerals. The column is split into two compartments, each containing one of the two relevant components of meaning, i.e., SCALE and NUM. The lines below indicate how the meaning components are pronounced by individual numerals. The same logic is followed in the object-counting column on the very right. The comparison of the two columns yields the symmetric pattern in the first line, followed by the idiosyncratic pattern, the asymmetric pattern and the inverse pattern.

The two bottom lines show additional logical possibilities of how the meaning components could be lexicalized. The line labelled as PRED₁ (‘predicted pattern #1’) is actually the same as the one above it, i.e., the one depicting the inverse pattern. The only difference is that β is an overt marker. Pure examples of such cardinal numerals are hard to find in our sample. What usually happens in candidate languages is that β does not only encode the object-counting function, but it simultaneously also expresses nominal class of the counted noun. Notice that this is so even in the case of German 1 (recall Table 4).

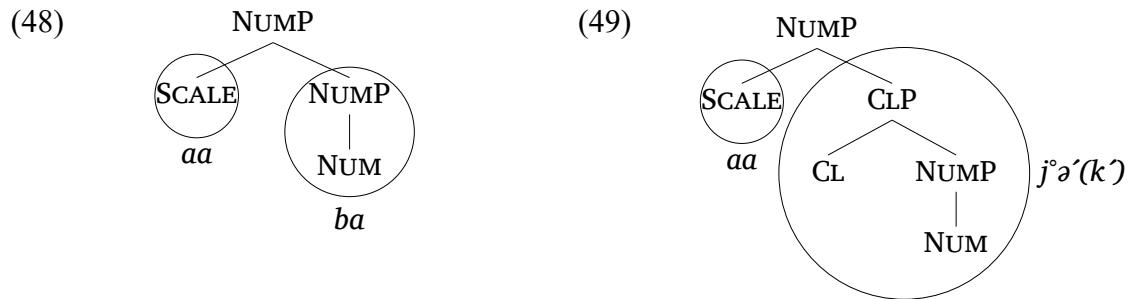
Taking this confound temporarily out of the picture (though we will return to it shortly), we can classify Abkhaz cardinals 2–10 as an instance of the predicted type PRED₁. This is shown in Table 6. In the left-hand column, we see the abstract-counting numerals, which are clearly complex. The right-hand column gives the object-counting numerals for human-denoting nouns. Here, the object-counting numeral has the suffix *-j°á(k’)* which replaces the abstract-counting *-ba* (Hewitt 1979, 2010; see also Chirikba 2003).²¹ We can model this correspondingly

²¹ In fact, the forms of Abkhaz abstract-counting numerals are also used to quantify over inanimate entities (see Section 6 for the discussion of the interplay between the abstract/object counting and gender/noun class). We would like to thank Viacheslav Chirikba for his comments on the Abkhaz data.

to the German 1 case, see (48) and (49) for Abkhaz 8, just with the CLP suffix overt (compare (46) and (47)).

NUMBER	ABSTRACT	OBJECT
4	<i>pš'-ba</i>	<i>pš'-j°á(k')</i>
5	<i>x°-ba</i>	<i>x°-j°á(k')</i>
6	<i>f-ba</i>	<i>f-j°á(k')</i>
7	<i>bəž'-ba</i>	<i>bəž'-j°á(k')</i>
8	<i>aa-ba</i>	<i>aa-j°á(k')</i>

Table 6. Abkhaz cardinal numerals



Turning now to the second predicted pattern, i.e., PRED₂ in Table 5, we must admit that we do not have a clear example of this numeral type. One potential candidate are cardinals higher than 1 in Akatek (Mayan), which allow for classifier stacking, see (50). In particular, Akatek numeral classifiers can co-occur with sortal classifiers (Zavala 2000, Aikhenvald 2000).²²

- (50) a. ox-eb' jilan 'aan Akatek
 three-CL₁ CL₂ corncob
 'three corncobs'
- b. kaa-(e)b' b'ilan poon yalixh-taj.
 two-CL₁ CL₂ plum small-PL
 'two small plums'

The examples in (50) indicate that it is possible to have multiple morphemes after the numeral in constructions where the numeral fulfills the object-counting function. This is in line with the

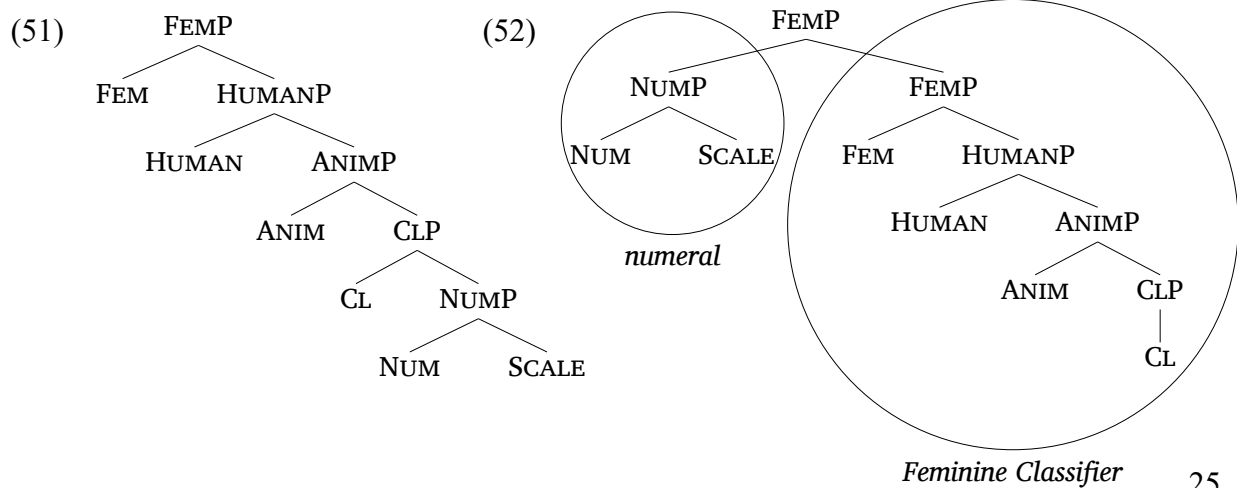
²² Actually, Akatek allows for stacking as many as 3 classifiers in a row. Notice, however, the distinction between numeral/sortal and noun classifiers. Importantly, numeral/sortal classifiers can be used only twice in a phrase (Zavala 2000, Aikhenvald 2000). Furthermore, noun classifiers have many functions which are unrelated to the issues discussed in this paper. In any case, due to the lack of data we will leave this issue for future research.

prediction in Table 5, where the numeral root is followed by two markers when used as an object-counting form. However, the example is not entirely conclusive because we do not know what Akatek abstract-counting forms look like. The list of cardinals accompanied with a brief comment in Zavala (1992) suggests that Akatek numerals higher than 1 do not occur bare but always take an additional morpheme. If this is indeed the case, our prediction is borne out but so far we did not have an opportunity to thoroughly test arithmetic environments in Akatek.

We end this section by restating the conclusion that the proposed system successfully derives all the attested types of cardinal numerals. The only loose end is the issue of potential over-generation. In particular, we predict the existence of an additional (scarce) pattern, where abstract-counting cardinals occur with a special affix while the object-counting function requires the stacking of two morphemes after the numeral. Akatek cardinals higher than 1 may be an instance of such a numeral type but due to the lack of data the issue remains unresolved.

6. Gender in object-counting numerals

Before we conclude, we would like to briefly indicate how we approach data where the shape of the classifier on the object-counting numeral is dependent on the morphological and/or semantic class of the counted noun. In the languages discussed here, such patterns arise prominently in German (recall Table 4), in Bulgarian (recall (21)–(22)), in Standard Arabic (recall (23)) and in general in all classifier languages with multiple types of classifiers (recall footnote 4). What we propose is that in languages like this, it is not the bare CLP that modifies the noun. In addition to the CLP (which is absolutely essential for object-counting), the numeral may also include additional features that add presuppositions concerning the nature of the modified noun (following the approach outlined in Sudo 2016). In (51), we show a rather rich structure of this kind, where several relevant features are added on top of the CLP, each introducing a presupposition of its own.



The pronunciation of such a structure proceeds on analogy with other cases. In (52), we show what happens in languages of the Japanese type, i.e., with asymmetric numerals. Recall that such numerals spell out NUMP. In order to allow for the spellout of FEMP, the NUMP must move out of the constituent in (51), yielding a structure such as the one in (52). Here a ‘human-feminine’ classifier attaches to the numeral, as indicated by the circle.

7. Conclusion

In this paper, we have examined cross-linguistic meaning/form correspondences between what we refer to as abstract-counting and object-counting cardinal numerals. The former are numerals used to refer to number concepts, e.g., in arithmetical statements. The latter are used as nominal modifiers in order to quantify over individuals. We have argued that object-counting numerals both syntactically and semantically contain abstract-counting numerals.

More specifically, we have postulated three syntactic heads that correspond to the primitive semantic ingredients of numerals: SCALE (defines a lower bounded set of natural numbers), NUM (turns such an interval into a number concept corresponding to the smallest integer in that interval) and CL (turns a number concept into a counting device). These ingredients are assembled into the invariant structure [CL [NUM SCALE]] for object-counting numerals and [NUM SCALE] for abstract-counting numerals.

In order to derive the surface patterns, we have adopted a nanosyntactic model of morphology (while admitting that alternative approaches are conceivable). The nanosyntactic account allowed us to formulate an account where the universal numeral structures are the input to the lexicalization procedure, which produces variable outputs depending on what the (late-inserted) lexical entries look like. Under this approach, all the variation thus reduces to the particular shape of the lexical entries available for a particular numeral.

Specifically, object-counting cardinals which are stored as the entire tree can serve both object- and abstract-counting function. On the other hand, numerals stored as [NUM SCALE] can be used only as abstract-counting expressions and additional morphology is required to pronounce CL, e.g., a classifier. Very rare cases of fully suppletive forms arise when a language has both types of lexical entries. Finally, in scarce cases of inverse marking (where abstract-counting cardinals appear to be more marked than object-counting ones), the pattern is derived by a very small cardinal stored simply as SCALE, so that both the abstract-counting function and the object-counting function each require some extra morphology. When the ‘classifier-like’ morpheme happens to be silent, the inverse pattern arises. When it is overt, we get a system

where both the abstract-counting numeral and the object-counting numeral are morphologically complex.

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