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The structure and meaning of label numerals

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ABSTRACT

This paper investigates the so-far neglected label use of numerals, as in *player number five*, and its relationship with the quantifying and the arithmetical function. The paper examines the conceptual nature of labeling and explores label constructions from a cross-linguistic perspective. In particular, the paper investigates marking patterns concerning derived label numerals in Slavic and classifier constructions in Japanese as well as data from Maltese and Wymysorys (Germanic). The paper argues that the arithmetical meaning is basic whereas the quantifying and the label meanings are derived by unrelated mechanisms. In order to account for the data, the paper proposes a morphosemantic analysis combining compositional semantics with Nanosyntax.

KEYWORDS numerals · labeling · reference · morphosemantics · Nanosyntax

1 INTRODUCTION

Until now, research on numerals has mainly focused on their quantifying uses, where the cardinal counts entities denoted by the modified NP (1-a). It is this quantifying meaning that is typically assumed as basic, as the numeral's semantic core of sorts (e.g., Rothstein 2017, Kennedy 2015, Ionin & Matushansky 2018). Yet, there are also other flavors of numerals, including arithmetical and label uses (1-b)–(1-c) (Bultinck 2005), where the numeral does not provide a cardinality of a collection of individuals, but rather refers to an abstract mathematical entity or designates an object associated with a particular number, respectively.

(1) a. Five girls shouted for joy. QUANTIFYING
b. Ten divided by five equals two. ARITHMETICAL
c. Player number five scored the winning goal. LABEL

The research presented in this paper is inspired by the following question: What is the relationship between the arithmetical, the quantifying and the label meaning of numerals? My main aim is to explore the similarities and differences in properties of 'five' in (1-a)–(1-c) from a cross-linguistic perspective with emphasis on Slavic and classifier languages, exemplified for the most part by Czech and Japanese, respectively. In particular, I will be most interested in the label meaning (1-c) and various numerical forms that can express it, since until now this function has received very little attention in the literature (but see Hurford 1987, p. 167–168, Wiese 2003, p. 37–42 and Bultinck 2005, p. 119–129 for notable exceptions).

Based on the cross-linguistic study of morphological relations between the three functions, I postulate that the arithmetical meaning is basic, whereas the quantifying and the label meaning are derived from it semantically. Based on this idea, I propose a uniform morpho-semantic system combining standard compositional semantics with a nanosyntactic view of morphology (building on Wągiel & Caha 2020, 2021) that allows for deriving the shape and meaning of the three types of numerals across the languages discussed.

The paper is outlined as follows. In §2, I demonstrate how the three uses of numerals under consideration differ from a linguistic point of view and discuss the core conceptual properties of the label function. In §3, I compare labels with ordinals and show that the two are distinct linguistic objects both syntactically and semantically. In §4, I examine various types of label numerals across languages with special focus on Slavic and Japanese. The data investigated indicates that label numerals can be morphologically more complex than arithmetical numerals but not vice versa and that they are not formed from quantifying numerals if there is a distinction between quantifying and arithmetical numerals in a language. §5 presents additional cross-linguistic evidence from the co-lexicalization patterns of the word 'number' further suggesting that the quantifying and the label function are independently derived from the more primitive arithmetical meaning. In §6, I propose a set of three semantic components corresponding to the three flavors in question and show how they can combine compositionally to derive the quantifying and the label meaning from the arithmetical core. In §7, on the other hand, I demonstrate how various types of morphological marking patterns discussed in §4 can be derived within a nanosyntactic system fed by the proposed semantic components. Finally, §8 concludes the paper.

2 HOW IS THE LABEL FUNCTION OF NUMERALS DIFFERENT?

Intuitively, the three functions in (1) are conceptually different (cf. Wiese 2003, Bultinck 2005, Rothstein 2017). While the arithmetical function concerns reference to a number concept, and thus allows us to talk about abstract arithmetical objects and relations between those objects, the quantifying and the label use establish two different types of association between those abstract objects and other kinds of entities. The quantifying function enables counting entities denoted by the modified NP via mapping of a collection of individuals onto a number corresponding to the cardinality of that collection, whereas the label meaning seems to associate an entity with a number in an arbitrary manner in order to provide means for identification, simply to help keep track of that entity. The distinction in question is also linguistically relevant.

2.1 DISTINGUISHING THE THREE FUNCTIONS IN LANGUAGE

Different linguistic properties of arithmetical, quantifying and label uses of numerals seem to stem from the difference in their semantics. First of all, numerals can appear in environments calling for a numeric value (2-a) only on their arithmetical use. The quantifying and the label meaning are illicit in such contexts (2-b)–(2-c).

(2) a. Five times two equals ten.
b. #Five things times two things equals ten things.
c. #Thing number five times thing number two equals thing number ten.

Second, arithmetical objects have properties such as being an even, prime or a Fibonacci number that cannot be predicated of entities of other types (3) (Rothstein 2017).[1]

(3) a. Five is an integer.
b. #Five things are an integer.
c. #Thing number five is an integer.

Furthermore, certain grammatical constructions give rise to different truth conditions depending on what type of numeral is employed (4). For instance, the dimension of comparison in (4-a) is different than that in (4-b)–(4-c). In the former case, it is the

[1] Of course, (3-c) would be felicitous if *thing number five* referred to a number. But in that case the felicity of the sentence has nothing to do with the properties of the label numeral.

relative ordering on the number line, whereas in the latter it is the (physical) size of compared entities, e.g., (4-b) and (4-c) would not be true if one compared five apples with six blueberries or a cauliflower with a radish, respectively.

(4) a. Five is smaller than six. ORDERING
b. Five things are smaller than six things. SIZE
c. Thing number five is smaller than thing number six. SIZE

On the other hand, only quantifying numerals are compatible with prequantifiers such as *all* (5) (see, e.g., Babby 1987).

(5) a. All five things that we saw yesterday are odd.
b. #All five is an odd number.
c. #Thing number all five is odd.

The same pattern can be observed with other prequantifiers such as Polish *(nie)całe* '(not) entire' and *dobre* 'good' (6) (see, e.g., Miechowicz-Mathiasen 2011, Willim 2015).

(6) a. Ania zjadła { niecałe / dobre } pięć ciasteczek.
Ania ate not.entire good five cookies.GEN
'Ania ate { almost five cookies / a good five of cookies }.'
b. #{ Niecałe / dobre } pięć to liczba rzeczywista.
not.entire good five COP number real
Intended: '{ Almost / A good } five is a real number.'
c. #Ania wsiadła do tramwaju numer { niecałe / dobre } pięć.
Ania took to tram.GEN number not.entire good five
Intended: 'Ania took tram number { almost / a good } five.' (Polish)

Finally, only quantifying numerals give rise to scalar implicatures (7) (see Bultinck 2005). While (7-a) can have the lower bound, i.e., *at least*, interpretation, arithmetical and label numerals receive no such reading and are always interpreted as bilaterally bound.

(7) a. You must take five cards to continue. ✓AT LEAST
b. You must multiply two by five to get ten. #AT LEAST
c. You must take bus number five to get to the hospital. #AT LEAST

Likewise, only in (8-a) can the main clause be felicitously continued by *if not more*.

(8) a. John took five cards, if not more.
b. #Two multiplied by five equals ten, if not more.
c. #John took bus number five, if not more.

I conclude that also from a purely linguistic perspective the arithmetical, the quantifying and the label function of numerals are very different. Only the arithmetical meaning is compatible with mathematical environments. On the other hand, label numerals pattern with quantifying numerals in that the domain of comparison in comparative constructions concerns size of individuals rather than relative ordering. Finally, arithmetical numerals and labels differ from quantifying numerals in that they resist modification by prequantifiers and do not give rise to scalar inferences. Table 1 summarizes the differences.

Having demonstrated how the three functions in question are distinguished linguistically, let us now discuss what labeling is.

2.2 LABELING

Labeling can be viewed as a form of naming. At its core, it provides means for identification of an entity in a given context through its association with a unique symbol. In this way, the labeled object is distinguished from other, typically similar, entities in

USE	MATH CONTEXTS	PREQUANTIFIERS	SCALAR INFERENCE	COMPARISON: SIZE
ARITHMETICAL	✓	×	×	×
QUANTIFYING	×	✓	✓	✓
LABEL	×	×	×	✓

Table 1: Properties of arithmetical, quantifying and label uses of numerals

a set, and thus can be easily recognized and traced. In the case of numerical labeling, this mechanism is often called nominal number assignment (Wiese 2003, p. 37–38; see also Bultinck 2005, p. 119), but labeling is by no means limited to numbers and virtually anything can be used as labels.

The only restriction is that a set of symbols can be used for labeling only insofar as the symbols in that set are used uniquely for each distinct entity via one-to-one mapping between a set of labeled entities and a given set of symbols. Other than that there are no requirements concerning what can function as labels. Of course, they can be natural numbers (9-a), but they can start at an arbitrary point and need not be consecutive, e.g., the even numbers in (9-b) label women's clothing sizes according to the German convention. They can also be letters (9-c) or combinations of numbers, abbreviations and words (9-d), or even colors since, e.g., the Lisbon Metro system distinguishes the lines through (9-e). Moreover, the set of symbols employed as labels can change over time, e.g., it can expand as new objects are labeled.

(9) a. {1, 2, 3, 4, 5, …}
b. {32, 34, 36, 38, 40, …}
c. {a, b, c, d, e, …}
d. {1, 2, 3, 95, 98, 2000, XP, Vista, 7, 8, 10, …}
e. {blue, yellow, green, red, …}

Crucially, in nominal number assignment the actual values corresponding to the label numerals are irrelevant, because the numbers do not indicate any kind of quantity, measurement or rank. In other words, labels provide no information other than that required for unique identification in a given context. The only thing that matters is that at a given time every labeled entity is associated with a unique number. This makes labels different not only from quantifying and arithmetical numerals, but also from ordinals.

3 LABELS VS. ORDINALS

In the literature, label constructions are sometimes assumed to be a type of ordinal numerals, specifically syntactically derived ordinals, as opposed to morphologically derived ones such as *fifth* (Hurford 1987, p. 167–168; Barbiers 2007, Meyer et al. 2020). Though at first sight such a view might seem appealing, in fact there is both syntactic and semantic evidence suggesting that the two types of expressions differ significantly.

First of all, at least in some languages there is a syntactic difference between labels and ordinals. For instance, in Dutch in environments such as (10) ordinals require the definite article, whereas label constructions pattern with proper names in that they disallow it (Barbiers 2007, p. 878).

(10) a. *(De) tweede kandidaat is weggegaan.
the second candidate has left
'The second candidate has left.'
b. (*De) kandidaat twee is weggegaan.
the candidate two has left
'Candidate number two has left.'

c. (*De) Peter is weggegaan.
the Peter has left
'Peter has left.' (Dutch)

Second, the two categories in question differ with respect to their referential properties. While labels seem to have a fixed reference in a given context, reference of ordinals is more flexible. This contrast is illustrated in (11) (Barbiers 2007, p. 878).

(11) We have five candidates, candidate number one, two, three, four and five. Normally, candidate five would be the fifth candidate that we will interview today, but since candidate four is ill, candidate five will be the fourth candidate today.

Furthermore, while ordinals give rise to certain existence inferences, labels do not (12)–(13). For instance, from the sentence in (12-a) it follows that there are or were other consecutive players (12-b). On the other hand, (13-a) does not indicate the existence of players labeled with lower numbers (13-b), because athletes typically choose an arbitrary jersey number of their liking. Rather, (13-a) simply identifies the relevant individual via association with the number five.

(12) a. That is the fifth player.
b. ⇝ There are or were the first, second, third and fourth players.

(13) a. That is player number five.
b. ⇝̸ There are or were players number one, two, three and four.

Of course, in some particular cases labels can indicate the existence of other objects along with (12), e.g., if there is building number five on a street, there is typically also building number four on that street. Crucially, however, unlike in the case of ordinals, this is merely because of non-linguistic conventions of urban planning etc. Numerous other examples show that in the absence of such a non-linguistic convention no such effect arises, e.g., there is Chanel No. 5 but no Chanel No. 4, there is Peugeot 508 but no Peugeot 507 etc.

Finally, only ordinals give rise to scalar implicatures, compare (14)–(15). For instance, the most natural interpretation of (14-a) is that in order to get to the next round you need to finish at least fifth (14-b). On the other hand, as already discussed in §2.1, recall (7), labels do not license such inferences and one cannot deduce (15-b) from (15-a).

(14) a. You must finish fifth in order to get to the next round.
b. ⇝ If you finish fourth, you will get to the next round.

(15) a. You must take bus number five in order to get to the hospital.
b. ⇝̸ If you take bus number { four / six }, you will get to the hospital.

Based on the contrasts examined above, I conclude that there is no evidence justifying treating label constructions as a type of ordinals. On the contrary, the two types of expressions differ significantly both in terms of syntactic and semantic properties and labels seem to share more properties with proper names than with ordinals.

In the next section, I will investigate morphological marking patterns concerning the shape of label, quantifying and arithmetical numerals from a cross-linguistic perspective.

4 FORM OF LABEL NUMERALS

Though the English data discussed in the previous sections suggest that the shape of the numeral is the same irrespective of whether it expresses the quantifying, the arithmetical or the label meaning, in fact languages often distinguish formally between these functions. In the past, some attention was dedicated to the morphological distinction between quantifying and arithmetical numerals (Greenberg 1978, Hurford 1998, 2001). Recent research suggests that when they differ, quantifying numerals are typically morphologically more complex than arithmetical numerals (Wągiel & Caha 2021; pace Greenberg 1978). In this section, I will examine how label numerals fit into the overall picture.

4.1 SUPPLETIVE NUMERALS IN MALTESE

Let us begin with two data points from Maltese. In this language, there are two morphologically unrelated forms corresponding to 'two', specifically *żewġ* and *tnejn* (Borg 1974, Hurford 1998). The two expressions differ in their distribution; for instance only the former can be used as a prenominal modifier to count entities denoted by the modified NP (16).

(16) a. żewġ nisa
two.Q women
'two women'
b. *tnejn nisa
two.A women
Intended: 'two women' (Maltese)

Hurford (1998) suggests that the distinction between the two forms reflects the difference between the quantifying and the arithmetical meaning.[2] While *tnejn* is felicitous in mathematical environments (see Borg 1987), the quantifying form *żewġ* cannot occur in such contexts.

(17) a. Tnejn u tnejn jagħmlu erbgħa.
two.A and two.A make four
'Two and two make four.'
b. *{Tnejn / Żewġ} u żewġ jagħmlu erbgħa.
two.A two.Q and two.Q make four
Intended: 'Two and two make four.' (Maltese)

Interestingly, as evidenced in (18), label constructions require the arithmetical numeral form *tnejn* since *żewġ* is unacceptable as a label.

(18) a. ix-xarabank numru tnejn
DEF-bus number two.A
'bus number two'
b. *ix-xarabank numru żewġ
DEF-bus number two.Q
Intended: 'bus number two' (Maltese)

Further evidence supporting this pattern comes from classifier languages. To illustrate, let us examine the relationship between the three functions under discussion in Japanese.

4.2 CLASSIFIER CONSTRUCTIONS IN JAPANESE

It is well known that in classifier languages such as Japanese bare numerals cannot combine directly with nominal expressions. As demonstrated in (19), in order to express the quantifying meaning, an additional element known as the classifier must follow the numeral root. In (19-b), *ko* is a general classifier.

(19) a. *go-no ringo
five-GEN apple
Intended: 'five apples'

[2] It should be noted that Borg (1974) proposes to explain the different distribution of *żewġ* and *tnejn* in purely syntactic terms. For the sake of space, I will not compare the two approaches here.

b. go-ko-no ringo
five-CLF-GEN apple
'five apples' (Japanese)

On the other hand, mathematical environments require bare numerals (20). Classifier constructions cannot express the arithmetical meaning even if they consist of the general classifier, which in principle can be used to designate any type of object.

(20) a. Juu waru go-wa ni-da.
ten divide five-TOP two-COP
'Ten divided by five is two.'
b. #Juu-ko waru go-ko-wa ni-ko-da.
ten-CLF divide five-CLF-TOP two-CLF-COP
Intended: 'Ten divided by five is two.' (Japanese)

Furthermore, classifier constructions are illicit in label environments. In Japanese, the label function is expressed by the morpheme *ban*. As evidenced by the contrast in (21), *ban* has to attach to the bare numeral and is unacceptable with a classifier construction.

(21) a. go-ban-no basu
five-LBL-GEN bus
'bus number five'
b. *go-ko-ban-no basu
five-CLF-LBL-GEN bus
Intended: 'bus number five' (Japanese)

The evidence from Japanese indicates two important things. First, it corroborates the observation from Maltese that the label function is not based on the quantifying one. Otherwise, one would expect (21-b) to be acceptable. Second, on the assumption that morphology expresses semantics, the patterns in (20), on the one hand, and in (19) and (21), on the other, suggest that the arithmetical meaning is more basic than the quantifying and the label meaning both of which seem to be more complex and derived from the arithmetical core. With these findings in mind, let us now turn to Slavic data.

4.3 DERIVED LABEL NUMERALS IN SLAVIC

As in English, the label function can be expressed in Slavic by the construction in which the NP is followed by the basic numeral form, which can also be employed for the quantifying and the arithmetical meaning, preceded by the word 'number' (22)–(23).

(22) a. pět hráčů
five players.GEN
'five players'
b. hráč číslo pět
player number five
'player number five' (Czech)

(23) a. pięć autobusów
five buses.GEN
'five buses'
b. autobus numer pięć
bus number five
'bus number five' (Polish)

More interestingly, however, in addition to the construction in (22-b) and (23-b) Slavic languages also have specialized label numerals. Across Slavic, these dedicated expressions are derived by the suffixes *-ka* and *-ica*. Table 2 provides an overview of the label forms for the numerals corresponding to 5 in selected major languages of every branch of Slavic (BCMS stands for Bosnian/Croatian/Montenegrin/Serbian).

LANGUAGE	NUMBER	CARDINAL	LABEL
Czech	5	pět	pětka
Polish	5	pięć	piątka
Russian	5	pjat'	pjaterka
Slovenian	5	pet	petka/petica
BCMS	5	pet	petica

Table 2: Cardinal and label 'five' in Slavic

Though there are a number of interesting differences in their productivity and distribution, e.g., Polish derives label forms with *-ka* up to 999 while Russian has them only for 2–10, 20 and 30, all Slavic label numerals are morphosyntactically nominal expressions used to refer to objects that can be identified via nominal number assignment. Though very often they appear bare, the noun specifying what entity is labeled can optionally precede the label numeral, as in (24)–(25). In the absence of the noun, this information is typically provided by the context.

(24) (Tramvaj) pět-ka vyjede na novou trať v listopadu.
tram five-LBL go.out.FUT on new.ACC track.ACC in November.LOC
'Tram number five will head out on the new track in November.' (Czech)

(25) (Gracz) piąt-ka przyjmuje podanie i oddaje strzał na bramkę.
player five-LBL receives pass.ACC and gives shot.ACC on goal.ACC
'Player number five receives the pass and shoots at the goal.' (Polish)

Similar to classifier constructions in Japanese, Slavic label numerals exhibit uniform behavior in that they cannot be felicitously used in mathematical statements, which require basic forms that also appear in quantifying contexts (26)–(27). This, in turn, suggests that the semantics of labels is very different from their quantifying counterparts.

(26) a. Dva-krát pět se rovná deset.
two-times five REFL equals ten
'Two times five equals ten.'
b. #Dvoj-ka krát pět-ka se rovná desít-ka.
two-LBL times five-LBL REFL equals ten-LBL
Intended: 'Two times five equals ten.' (Czech)

(27) a. Dziesięć dzielone przez pięć równa się dwa.
ten divided by five.ACC equals REFL two
'Ten divided by five equals two.'
b. #Dziesiąt-ka dzielona przez piąt-kę równa się dwój-ka.
ten-LBL divided by five-LBL.ACC equals REFL two-LBL
Intended: 'Ten divided by five equals two.' (Polish)

The data above show that Slavic derived label numerals are both morphologically and semantically complex. They pattern with classifier constructions in being incompatible in arithmetical contexts. Before we conclude this section, let us discuss the final dataset, this time from Germanic.

4.4 LABEL NUMERALS IN WYMYSORYS

Dedicated label numerals are not a Slavic idiosyncrasy and they are also attested in other languages, e.g., in Wymysorys (an endemic Germanic language spoken in the town of Wilamowice in Southern Poland, see Wicherkiewicz 2003, Andrason & Król

2016). Wymysorys label numerals are derived by the suffix *-er* from basic numeral forms (Andrason & Król 2016, p. 59–60). As witnessed in Table 3, they are formally distinct from ordinals, which are derived by the suffix *-ty/-dy* (Andrason & Król 2016, p. 57–59).[3]

NUMBER	CARDINAL	ORDINAL	LABEL
4	fiyr	fjydy	fjyrer
5	fynf	fynfty	fynfer
6	záhs	záhsty	záhser
7	zejwa	zejwdy	zejwer

Table 3: Cardinal, ordinal and label numerals in Wymysorys

In Wymysorys, derived labels are used to identify various types of objects, including lines of public transportation but also year dates and cohorts born in a given year. An example of a construction with the derived label numeral is given in (28).

(28) Der fynf-er oütabüs ej gykuma.
the five-LBL bus is come
'Bus number five has come.' (Wymysorys)

What is important from the perspective of this paper is that similar to Slavic, Wymysorys derived label numerals are illicit in arithmetical environments (29).

(29) a. Fynf möł cwe ej cyn.
five times two is ten
'Five times two equals ten.'
b. #Fynf-er möł cwàj-er ej cyn-er.
five-LBL times two-LBL is ten-LBL
Intended: 'Five times two equals ten.' (Wymysorys)

The cross-linguistic evidence discussed in this section suggests two empirical conclusions. First of all, based on morphological marking, the arithmetical meaning appears to be basic, whereas the two other functions in question are derived. Second, the quantifying and the label meaning are unrelated and they both seem to stem from the arithmetical meaning via independent mechanisms. In the next section, I will provide another type of evidence indicating that these conclusions are correct.

5 EVIDENCE FROM CO-LEXICALIZATIONS

In many languages, an additional expression can be optionally used alongside the numeral in order to indicate its quantifying, arithmetical or label use. Sometimes, the same lexical item can introduce all of the above functions. For instance, English employs a single noun, namely *number*, to indicate cardinality, to designate a mathematical object and to signal that an entity is identified via association with the relevant integer (30).

(30) a. The cats are five in number.
b. The number five is odd.
c. tram number five

More often, however, lexicons develop a different word for at least one of the functions in question, though ways in which meanings and forms correspond to each other vary. In what follows, I will examine permissible patterns of co-lexicalization of 'number' in Slavic as well as a couple other languages. This type of evidence is rarely considered in

[3] Notice that for the sake of simplicity I ignore here the fact that across speakers the numeral 'five' and its derivates have two possible forms differing in the place of articulation of the nasal, e.g., *fynf/fymf* 'five' ~ *fynfty/fymfty* 'fifth' etc. (Andrason & Król 2016, p. 56–60).

formal semantics. However, I believe that looking at how certain parts of lexicon are structured cross-linguistically can be instructive. Arguably, identifying robust patterns of lexical syncretism can reveal that some meanings have more in common than others and, in some cases, that certain categories are 'unthinkable', i.e., theoretically possible but empirically unrealized.[4] Consequently, one can gain valuable hints regarding how to account for related meanings formally.

Let us first consider Bosnian/Croatian/Montenegrin/Serbian (BCMS), which displays the very same pattern as English. As witnessed in (31), the noun *broj* 'number' can felicitously indicate the quantifying, arithmetical and label function. An example of this pattern outside Slavic is, e.g., Portuguese *número* 'number'.

(31) a. Broj mačaka je pet.
number cats.GEN is five
'The number of cats is five.'
b. Broj pet je neparan.
number five is odd
'The number five is odd.'
c. tramvaj broj pet
tram number five
'tram number five' (BCMS)

On the other hand, in Polish there is a distinction between *liczba* and *numer*, both 'number'. The first can designate cardinality or an arithmetical entity whereas the latter can only be used as an indicator of the label function (32).

(32) a. {Liczba / #Numer } kotów to pięć.
number$_1$ number$_2$ cats.GEN COP five
'The number of cats is five.'
b. {Liczba / #Numer } pięć jest nieparzysta.
number$_1$ number$_2$ five is odd
'The number five is odd.'
c. tramwaj { #liczba / numer } pięć
tram number$_1$ number$_2$ five
'tram number five' (Polish)

A special subtype of this pattern is found in German (33). In this language, the expression introducing the quantifying function is derived from the noun indicating the arithmetical use, compare *Anzahl* and *Zahl* 'number'. On the other hand, the expression of the label function, i.e., *Nummer* 'number', is morphologically unrelated to either of the two.

(33) a. Die Anzahl der Katzen ist funf.
the number$_1$ the.GEN cats is five
'The number of cats is five.'
b. Die Zahl funf ist ungerade.
the number$_2$ five is odd
'The number five is odd.'
c. Straßenbahn Nummer funf
tram number$_3$ five
'tram number five' (German)

An inverse asymmetry is attested in Czech and Slovak. In both cases, the arithmetical and label functions are co-lexicalized. For instance, in Slovak the lexeme *číslo* 'number' is used for arithmetic and labeling whereas *počet* 'number' signals the quantifying function (34).

[4] This way of viewing data has been successful in lexicology, e.g., in generalizations about kinship terms (see, e.g., Hage 1997, Truong 2020).

(34) a. Počet mačiek je päť.
number$_1$ cats.GEN is five
'The number of cats is five.'
b. Číslo päť je nepárne.
number$_2$ five is odd
'The number five is odd.'
c. električka číslo päť
tram number$_2$ five
'tram number five' (Slovak)

Finally, Bulgarian exhibits a pattern with no co-lexication, i.e., each of the discussed functions is signalled by a morphologically distinct expression. As witnessed in (35), *broj* is for quantification, *čislo* is for arithmetic and *nomer* is for the label function.

(35) a. Tramvai-te sa pet na broj.
trams-DEF are five on number$_1$
'The trams are five in number.'
b. Čislo-to pet e nečetno.
number$_2$-DEF five is odd
'The number five is odd.'
c. tramvaj nomer pet
tram number$_3$ five
'tram number five' (Bulgarian)

The patterns can be summarized in Table 4. Interestingly, the pattern that is not attested in the sample is a case of non-contiguous co-lexicalization where the quantifying and the label function are expressed with the same form while the arithmetical function is expressed by a different lexical item. Perhaps surprisingly, this result strongly resembles the well-known *ABA principle (Bobaljik 2012).

LANGUAGE	QUANTIFYING	ARITHMETICAL	LABEL
BCMS	A	A	A
Polish	A	A	B
Slovak	A	B	B
Bulgarian	A	B	C
unattested	A	B	A

Table 4: Co-lexicalization of 'number'

Whether a language that has a term for the quantifying and the label function to the exclusion of the arithmetical function can be found is an empirical issue. So far, the data in the analyzed sample suggest that while the quantifying and the label meaning are unrelated, they both seem to stem from the arithmetical function. On the assumption that co-lexicalization reflects a deep relationship between concepts in natural language, such an explanation seems intuitively right. If both the quantifying and the label meaning are derived from the arithmetical meaning, the attested co-lexicalization patterns are unsurprising. On the other hand, if the quantifying meaning were basic and the other two independently derived from it, then one would expect the unattested ABA pattern.

With this in mind, let us now propose an account that will capture the relationship between the arithmetical, the quantifying and the labeling meaning as well as the morphosemantics of Slavic and Japanese numerical expressions.

6 MEANING

Let us begin with several assumptions concerning numerals that I adopt for the purpose of the analysis.

6.1 ASSUMPTIONS

In this paper, I follow Krifka (1989) in assuming that counting can be captured as a type of measurement, specifically measurement of a quantity of a plural individual in discrete units. For this purpose, I assume the # operation that yields a measure function mapping pluralities of entities to a natural number corresponding to the number of singular entities making up those pluralities.

In addition, I embrace the view that across languages numerals differ with respect to their meaning (Krifka 1995, Bale & Coon 2014, Sudo 2016, Wągiel & Caha 2020, 2021). Sometimes, they have the # operation inherently built in their semantics, which allows them to combine with nominal expressions directly. In other cases, though, they do not, and thus require additional morphology, e.g., classifiers, in order to be turned into counting devices. Notice that the adopted view goes against the standard approach, which postulates that classifiers compensate for semantic deficits of nominal expressions in languages in which nouns allegedly have mass-like semantics (e.g., Chierchia 1998, 2010, Borer 2005, Rothstein 2010; for some arguments against the received view, see Bale & Coon 2014, Sudo 2016).

The adopted semantic view is supported by the syntactic typology regarding ordering of classifiers, numerals and nouns (Greenberg 1972, Cinque 2020). Cross-linguistically, various configurations of these three categories are possibly as long as the numeral and the classifier are adjacent. Consequently, among six logically possible orders, the sequences *CLF > N > NUM and *NUM > N > CLF are not attested, which suggests that the numeral and the classifier form a syntactic unit. In addition, in languages such as Ch'ol and Japanese it is possible to front the NUM+CLF string to the exclusion of the noun (Bale et al. 2019, Tatsumi 2021). These facts receive a straightforward explanation under the hypothesis that [NUM+CLF] is a constituent.[5]

Finally, in accordance with the discussion in §2.2, I assume that labeling can be captured via (context-sensitive) one-to-one and onto mapping between a set of labeled objects and a given set of labeling entities. In the case of nominal number assignment, the set of labels is the set of numbers. The association of a given object with a number allows for an easy identification of that object in a given context.

Having discussed the relevant assumptions, let me now introduce the semantic components of the analysis, which builds on Wągiel & Caha's (2020, 2021) approach.

6.2 SEMANTIC PRIMITIVES

The fundamental idea is that the arithmetical meaning is the underlying semantic core of all numerals from which both the quantifying and the label meaning can be derived. For this purpose, I propose the three primitive components Num$_n$P (for 'number'), Cl (for 'classifier') and Lbl (for 'label') in (36)–(38).

The first component represents the lexical content of the numeral. The Num$_n$P in (36-a) is a proper name of a number concept and as such it refers to a particular numeric value, i.e., an abstract object of the primitive type *n*. Consequently, it can be used to express the arithmetical function. As indicated by the subscript, for each numeral there is

[5] Note, however, that the overall picture is not that simple because there are classifier languages, e.g., Mandarin, that do not allow for the NUM+CLF fronting (Zhang 2011). Nonetheless, even in Mandarin, when the classifier construction appears in predicate position or as a fragment answer, the noun is left out, whereas the classifier cannot be omitted. For a discussion of more problematic cross-linguistic data and comparison of different constituency structures concerning classifiers, see Dékány (2022).

a different Num_nP. For instance, the arithmetical use of *five* would have the representation in (36-b), which is the name of the natural number 5.[6]

(36) a. $[\![\text{Num}_n\text{P}]\!]_n = n$
b. $[\![\text{Num}_5\text{P}]\!] = 5$

The second ingredient is the Cl head, which expresses the quantifying function by introducing a classifier semantics.[7] As provided in (37-a), Cl shifts a name of a number concept (type *n*) to a counting device, which is taken here to be a predicate modifier equipped with Link's (1983) pluralization operator * coupled with the measure-function-yielding operation # (Krifka 1989).[8] To illustrate, after Cl takes Num_5P as its argument in (37-b), the resulting expression is a counting device of type $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$. It can combine with a property and return a set of pluralities consisting of five constituent members each such that they have the modified property.

(37) a. $[\![\text{Cl}]\!]_{\langle n,\langle\langle e,t\rangle,\langle e,t\rangle\rangle\rangle} = \lambda n_n \lambda P_{\langle e,t\rangle} \lambda x_e[{}^*P(x) \wedge \#(P)(x) = n]$
b. $[\![\text{Cl}]\!]([\![\text{Num}_5\text{P}]\!]) = \lambda P_{\langle e,t\rangle} \lambda x_e[{}^*P(x) \wedge \#(P)(x) = 5]$

Finally, the Lbl head in (38-a) provides a means for unique identification of an entity in a given context by introducing the standard ι operator and the labeling operation label parameterized with a context variable *c*, whose value is provided by the context. Thus, label establishes a context-sensitive relation between an entity and a natural number via one-to-one association. In this way, it essentially forges a name for the relevant entity. For instance, in (38-b) the Lbl shifts the number 5 to an expression that, when combined with a nominal property, yields a (contextually) unique individual that has that property and is identifiable by its association with 5.

(38) a. $[\![\text{Lbl}]\!]_{\langle n,\langle\langle e,t\rangle,e\rangle\rangle} = \lambda n_n \lambda P_{\langle e,t\rangle} \iota x_e[P(x) \wedge \text{label}_c(n,x)]$
b. $[\![\text{Lbl}]\!]([\![\text{Num}_5\text{P}]\!]) = \lambda P_{\langle e,t\rangle} \iota x_e[P(x) \wedge \text{label}_c(5,x)]$

With all the primitive ingredients in place, let us now consider the structures obtained from combining the proposed components.

6.3 STRUCTURES

The semantic ingredients in (36)–(38) combine in a compositional manner via the standard Function Application. The Num_nP simply expresses the arithmetical meaning of a numeral. For instance, the structure in (39) refers to the number 5 and as an object of type *n* fits into environments calling for numeric values such as mathematical statements.

(39) Num_5P_n
△
5

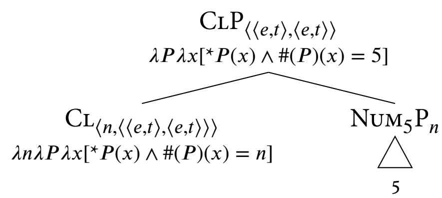
The quantifying meaning is more complex since it results from the Cl head attaching on top of a Num_nP in order to shift a number concept into a counting device. This gives rise to structures such as (40), where the meaning of the entire ClP is a predicate modifier equipped with the quantifying machinery. When (40) combines with an NP, the result is a set of pluralities such that each plurality in that set comprises five entities having the property denoted by that NP (41).

[6] Notice that Wągiel & Caha (2020, 2021) further decompose Num_nP into even more primitive components. Though such a decomposition is fully compatible with the analysis proposed here, for the sake of space and simplicity I will only assume Num_nP since this is entirely sufficient for capturing the phenomena discussed in this paper.

[7] Obviously, the meaning of natural language expressions dubbed 'classifiers' in languages such as Japanese is much richer than (37) since often classifiers also specify the type of counted entities (e.g., Sudo 2016).

[8] Note that the proposed system would work also with other approaches to numerals' meaning, as long as it is possible to shift an object of type *n* to a more complex quantifying semantics.

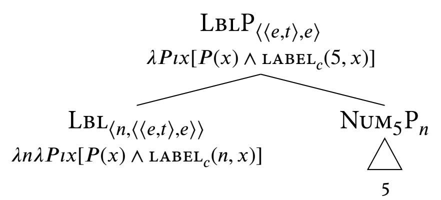
(40)



(41) $[\![\text{five players}]\!]_{\langle e,t\rangle} = \lambda x[{}^*\textsc{player}(x) \wedge \#(\textsc{player})(x) = 5]$

The label meaning, on the other hand, is expressed by the structure in (42). It is similar to (40) in that it is semantically complex and derived from the arithmetical meaning. The difference is that instead of the ClP on top of the Num_5P there is the LblP layer. The LblP as a whole denotes a function of type $\langle\langle e, t\rangle, e\rangle$ that turns a set of individuals into an entity that can be identified via its association with the number 5. Hence, after (42) combines with a noun, we obtain a singular term referring to the (contextually) unique object labeled with 5. For instance, the phrase *player number five* receives the semantics in (43).

(42)



(43) $[\![\text{player number five}]\!]_e = \iota x[\textsc{player}(x) \wedge \textsc{label}_c(5, x)]$

Having discussed the semantic part of the proposal, let us now demonstrate how the postulated meaning components can be expressed formally by different types of numerals.

7 DERIVATION

In §4 and 5, I investigated various kinds of meaning-form correspondences regarding the arithmetical, the quantifying and the label function of numerals. In this section, I will develop a morpho-semantic account that will allow us to assemble the shapes of Slavic and Japanese numerals from the semantic ingredients proposed in the previous section. For this purpose, I adopt a nanosyntactic approach, which is a realizational post-syntactic model of morphology based on late insertion (Starke 2009, Caha 2009).

7.1 NANOSYNTAX

In this paper, I adopt a version of Nanosyntax that includes spellout driven movement (Starke 2018, Baunaz & Lander 2018, Caha et al. 2019). The core idea of the approach is that syntactic structures are formed first from abstract meaningful features, which are then mapped onto their pronunciation during the so-called lexicalization procedure. The lexicon is viewed as a language-specific list of lexical items taken to be links between particular syntactic structures and phonological and/or conceptual representations. For our purposes, we will need two pieces of technology.

The first theoretical tool is the Superset Principle (Starke 2009). The definition in (44) is a nanosyntactic way of capturing the core idea behind late insertion, namely that lexical entries are not tailor-made for one specific function, but rather can express different functions depending on a syntactic environment. For instance, a structure $[\alpha\ [\beta\ \gamma]]$ can also pronounce $[\beta\ \gamma]$ as well as γ since both these structures are part of $[\alpha\ [\beta\ \gamma]]$.

(44) Superset Principle
A lexically stored tree L matches a syntactic node S iff L contains the syntactic tree dominated by S as a subtree.

The second theoretical tool is the Spellout Algorithm, which implements the idea of Cyclic Spellout (Starke 2018). As defined in (45), the Spellout Algorithm introduces three different spellout options for an FP formed by external merge. The first step is to simply find a match in the lexicon for the built FP and to spell it out. If this turns out to be impossible, (45) offers two different rescue strategies based on movement.

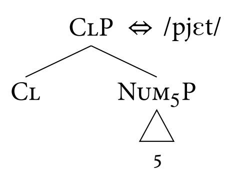
(45) Spellout Algorithm
Merge F and:
a. Spell out FP.
b. If (a) fails, move the Spec of the complement of F, and retry (a).
c. If (b) fails, move the complement of F, and retry (a).

Having discussed the basic mechanics, let me now demonstrate how it will allow us to account for arithmetical, quantifying and label numerals in Slavic and Japanese.[9]

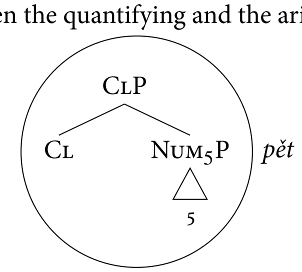
7.2 SPELLOUT

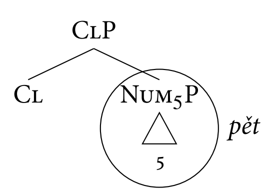
One of the observations in §4.3 is that in Slavic (just like in English), the very same form of the numeral can be used to express either the quantifying or the arithmetical function, recall, e.g., (22-a) and (26-a). In other words, Slavic numerals are ambiguous between these two functions. In the proposed system, this fact can be captured as a consequence of the essential property of late insertion, specifically that lexical entries are not suited for one particular meaning. In the following, I will demonstrate the account based on Czech.

I propose that the Czech numeral *pět* 'five' is stored in the lexicon as (46). In Nanosyntax, a lexical item is taken to be an instruction of the following sort: if syntax constructs the structure S, realize S by the exponent P. In the case of (46), the ClP derived by syntax should be pronounced as /pjɛt/.

(46)


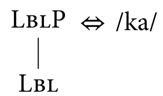
However, according to the Superset Principle in (44), a lexical entry can pronounce not only the maximal stored constituent, but also any subconstituent that is contained in it. This means that *pět* 'five' can either pronounce the entire ClP, as indicated by the circle in (47), which would give rise to the quantifying function of *pět* 'five', or *pět* can spell out only the Num$_5$P since it is contained in the lexically stored tree in (46), see (48). This second option allows the numeral to express the arithmetical meaning. As a result, the lexical item in (46) coupled with the Superset Principle explain the systematic ambiguity between the quantifying and the arithmetical function found in Slavic numerals.

(47)


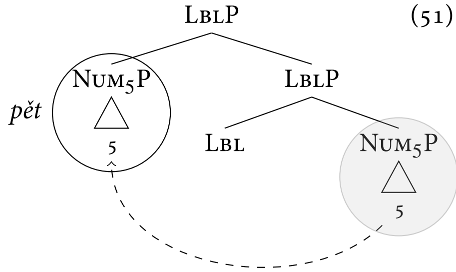
(48)


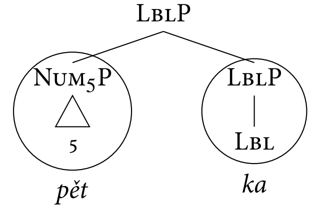
[9] The Wymysorys pattern is derived identically to the Slavic one, whereas extending the system to capture Maltese would require an additional assumption, which I will leave out in the interest of space (but see Wągiel & Caha 2020, 2021 for the implementation covering the distinction between the arithmetical and the quantifying 'two').

Now, how do we derive the label meaning? Clearly, (46) cannot express it since it lacks the LblP projection, and thus there is no match. In order to introduce the Lbl component, which provides the labeling semantics, another piece of morphology is needed. It could be the word *číslo* 'number', but I will focus here on derived label numerals. Therefore, I propose that the Czech label suffix *-ka* is stored in the lexicon as (49).

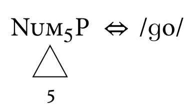
(49)


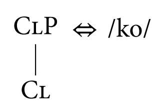
The Lbl cannot attach on top of ClP; rather it requires an argument of type *n*. For this purpose, (49) will be merged with the Num5P part of (46) indicted by the circle in (48). According to the Spellout Algorithm in (45), in a situation when spellout fails, the first rescue step is to move the Spec of the complement. However, in our case this option is undefined and the algorithm will proceed to the final step of the derivation procedure, which triggers movement of the complement of F, as illustrated in (50).[10] After the Num5P is displaced, the structure in (49) matches the lower LblP, as shown in (51), where the suffix *-ka* is inserted at the relevant node and the Czech label numeral *pětka* is derived.

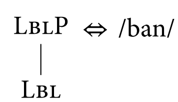
(50)


(51)


Let us now turn to Japanese. As discussed in §4.2, Japanese numerals differ from Slavic (and English) numerals in that they cannot express the quantifying function on their own. In order to capture this fact, I assume that the Japanese numeral *go* 'five' is stored as in (52). In addition, I postulate that the general classifier *ko* and the label suffix *ban* have the lexical entries in (53) and (54), respectively.

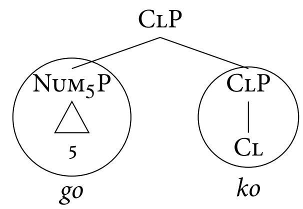
(52)


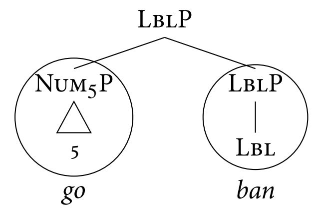
(53)


(54)


The entry in (52) is absolutely sufficient to express the arithmetical meaning, and thus the bare numeral *go* 'five' can felicitously appear in mathematical environments calling for an exact numeric value. However, since it comprises neither the ClP nor the LblP layer that would turn the number concept into a counting or a labeling device, respectively, it cannot be used either as a quantifying modifier or as a label expression. For this purpose, the Cl/Lbl shift needs to be introduced. The derivation, thus, follows the Spellout Algorithm in parallel to the case of the Czech *pětka*, recall (50)–(51). Consequently, after movement we obtain the desired structures in (55) and (56).

[10] In Nanosyntax, it is assumed that the movement in (50) leaves no trace.

(55) 

(56) 

I conclude that the proposed system captures both the semantic and the morphological relationships between the three types of numerals in Slavic and Japanese.

8 CONCLUSION

In this paper, I examined the previously understudied label function of numerals, as in *player number five*. I explored the manner in which it differs from the quantifying and the arithmetical function as well as how the three relate. I investigated a number of numerical expressions conveying the label meaning from a comparative perspective with a special emphasis on Slavic and Japanese. Based on cross-linguistic evidence, I postulated that the arithmetical meaning of numerals is basic. The quantifying and the label meaning are derived and they both syntactically and semantically contain the arithmetical core, represented in the proposed system by the Num$_n$P. Despite both being complex, these two functions are unrelated and arise via application of different semantic components on top of the arithmetical Num$_n$P. In particular, the quantifying meaning is the result of combining the Num$_n$P with the Cl head, thus [Cl Num$_n$P]. On the other hand, the label meaning is assembled as [Lbl Num$_n$P], where the Lbl provides a means for identification of an object in a given context via its association with a number designated by the Num$_n$P. Different forms of arithmetical, quantifying and label numerals then result from various ways in which the proposed components can be spelled-out by individual lexical items.

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ABBREVIATIONS

A	arithmetical	FUT	future
ACC	accusative	GEN	genitive
BCMS	Bosnian/Croatian/ Montenegrin/Serbian	LBL	label
		LOC	locative
CLF	classifier	Q	quantifying
COP	copula	REFL	reflexive
DEF	definite	TOP	topic

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