Chapter 2

Lexemes, categories and paradigms: What about cardinals?

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In Word and Paradigm frameworks such as Network Morphology (Corbett & Fraser 1993) and Paradigm Function Morphology (Stump 2001), categories and lexemes are taken as granted and usually associated with an inflectional paradigm relevant for all the lexemes in a given category. In Section 2, we explore the status of French cardinals as lexemes based on the characteristic properties defined by Fradin (2003): i) abstraction over form-variation, ii) autonomous forms, iii) stable meaning, iv) belonging to a major category, v) open-ended set of units that can serve as input and/or output of morphology. We start with the simple cardinals and argue, following Saulnier (2008)'s discussion, that French cardinals fit all the lexemic criteria but (iv), belonging to a major category, and should be considered full lexemes even though they constitute a sub-category of determiner, a minor category in Fradin's terms. In Section 3, moving from simple cardinals to complex ones, we show that the idiosyncratic morphophonological properties of French cardinals plead for a morphological analysis rather than a syntactic one, giving an analysis of their construction as multi-layered compounds. In Section 4, we describe the inflectional paradigms of French cardinals as dependent on their rightmost element using the Right Edge mechanism introduced by Miller (1992) and Tseng (2003) for other phenomena in French. In the conclusion, we show that some complex cardinals have to be analyzed as multi-layered morphological compounds due to their morphophonological idiosyncrasies but this does not entail that all complex cardinal should be. The fact that syntactic combinations of French cardinals do not respect lexical integrity indicates that to some extent, complex cardinals are in the shared custody of morphology and syntax.

1 Introduction

In this paper, following the lead of Saulnier (2008, 2010), we explore the status of French cardinals and their place in Word and Paradigm frameworks, within theories of morphology focusing on lexemes as their fundamental unit. In general, this topic poses interesting problems for linguistic theories:

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- Are they lexemes? To what category do they belong: determiners, nouns, adjectives?
- Are they built by syntax or in the lexicon?
- Is there an inflectional paradigm for cardinals? If so, where does it come from?

In Section 2, we explore the categorial status of simple cardinals. In Section 3, we argue that complex cardinals are lexemes, like simple cardinals, even though they constitute a subcategory of determiners.[1] We outline a syntagmatic analysis to create complex cardinals in morphology as compounds. In the last section, we propose an analysis of the inflectional paradigm of cardinals based on the Right Edge mechanism introduced by Miller (1992) and Tseng (2003) for other phenomena in French.

2 French cardinals: Lexemes?

In this section, we examine the lexical status of French cardinals.[2]

Following Fradin (2003: 102), we distinguish two types of atomic units in the lexicon: lexemes and grammemes. Lexemes are typically nouns, verbs, adjectives, adverbs, while grammemes are grammatical units such as prepositions, determiners, conjunctions. Fradin identifies the following characteristic properties of lexemes:

(1) a. It is an abstract unit to which word-forms are related; this unit captures the variations across word-forms.
   b. It possesses a phonological representation which gives it prosodic autonomy.
   c. Its meaning is stable and unique.
   d. It belongs to a category and can have an argument structure.
   e. It belongs to an open-ended set and can serve as output and input of derivational morphology.

Whatever the analysis of French complex cardinals such as *vingt-et-un* '21', simple cardinals like *vingt* or *un* are underived and therefore have to be listed in the lexicon. In what follows, we argue that simple cardinals in French pattern with lexemes rather than grammemes.

In French, the simple cardinals are the elements listed in (2) that serve as cardinals and as building blocks for complex cardinals.[3]

(2) *un* '1', *deux* '2', *trois* '3', *quatre* '4', *cinq* '5', *six* '6', *sept* '7', *huit* '8', *neuf* '9', *dix* '10', *onze* '11', *douze* '12', *treize* '13', *quatorze* '14', *quinze* '15', *seize* '16',

[1]This does not mean that all determiners are lexemes but rather that cardinals have to be treated as an exception.

[2]For complex cardinals, see Section 3.

[3]The elements *million* and *milliard* are not simple cardinals in French; their respective values are realized as *un million* ('one million') and *un milliard* ('one billion'). They semantically belong to the quantity noun series in *-aine* (see Table 2, p. 23)

vingt '20', *trente* '30', *quarante* '40', *cinquante* '50', *soixante* '60', *cent* '100', *mille* '1,000'

Simple cardinals have the properties (1b–c). They can be used as single word answers, meaning they have an autonomous phonological representation. They have straightforward semantics, denoting counting values.

2.1 Form variation abstraction

As for property (1a), while *un* '1' is the only simple cardinal varying in gender (M: [œ̃] *un*, F: [yn] *une*), many simple cardinals are subject to *liaison* (linking), a morphosyntactic phenomenon whereby French words can change in form depending on the phonological properties of the following word. For example, in (3), the adjective BON agrees in gender and number with the following noun, in both cases masculine and singular. But in a liaison context such as prenominally, the form bɔ̃ appears in (3a) in front of a word starting with a consonant (not a liaison trigger: ⊖) and the form bɔn appears in (3b) in front of a vowel-initial word (a liaison trigger: ⊕). Outside liaison context (⊘), adjectives assume the same form as in liaison context without trigger (⊘=⊖).[4]

(3) a. un bon collègue
   œ̃ bɔ̃⊖ kolɛg
   'a good colleague'

b. un bon ami
   œ̃ bɔn⊕ ami
   'a good friend'

c. bon à manger
   bɔ̃⊘ a mɑ̃ʒe
   'ready to eat'

Unlike adjectives, cardinals can have three different forms for the three contexts above.[5] For example, *six* '6' has different realizations (si, siz, sis) for the three contexts:

(4) a. in liaison context without a liaison trigger ⇒ si ⊖
   six souris
   si⊖ suʁi
   'six mice'

b. in liaison context with a liaison trigger ⇒ siz ⊕
   six écureuils
   siz⊕ ekyʁœj
   'six squirrels'

c. not in liaison context ⇒ sis ⊘
   six à attraper
   sis⊘ a atʁape
   'six to catch'

[4] For more details about the morpho-syntactic aspects of liaison see Bonami et al. (2004).
[5] See Plénat (2008), Plénat & Plénat (2011) and the citations therein for a detailed description.

Not all cardinals have different forms in all three contexts. Table 1 gives the five different patterns of syncretism found with the simple cardinals. Type A cardinals are not sensitive to liaison and thus display only one form; in type B the ⊖ and the ⊘ are identical and the ⊕ has an additional consonant at the end, while in type C all three forms are distinct. In type D, ⊖ is overabundant with a long form and a short form, and the long form is also used in the two other contexts. Type E is a variant of type B where instead of having an additional consonant for ⊕, the final fricative alternates between voiceless f and its voiced counterpart v.[6]

Table 1: Type of simple cardinal variation according to liaison

Type	Example	⊖	⊕	⊘	Cardinals
A	4	katʁ	katʁ	katʁ	4, 7, 11, 12, 13, 14, 15, 16, 30, 40, 50, 60, 1000
B	2	dø	døz	dø	1, 2, 3, 20, 100
C	6	si	siz	sis	6, 10
D	5	sɛ̃/sɛ̃k	sɛ̃k	sɛ̃k	5, 8
E	9	nœf	nœv	nœf	9

The simple cardinals in (2) have an associated form paradigm for liaison, which fit Fradin's property (1a). This property is part of the conceptual definition of lexeme; it is neither required nor sufficient by itself. Definite determiners which have form paradigms in French and German are not considered lexemes, while English adjectives are lexemes even though their forms do not vary.

We turn now to the two remaining properties (1d–e): belonging to an open-ended category and participating as the output and potentially the input of derivational morphology.

2.2 Morphological input

In French, simple cardinals clearly serve as input for several morphological derivations as summarised in Table 2 below (see Saulnier 2008, Fradin & Saulnier 2009, Saulnier 2010 for a detailed discussion).[7]

As bases for the ordinals, simple cardinals are part of a morphological category in terms of Van Marle (1985) namely the derivational domain of ordinals, but to satisfy (1d), simple cardinals have to belong to a unique morphosyntactic category.

[6] In the case of type E, there is also hesitation for the ⊕ form between nœv and nœf as they can both provide an onset for the following trigger unlike in type B.

[7] While belonging to the same series of nouns designating groups of approximate cardinality, *millier* ('thousand'), *million* ('million'), *milliard* ('billion') are derived from *mille* with different suffixes (*-ier*, *-ion*, *-iard*).

Table 2: Some derivations on French cardinals (adapted from Fradin & Saulnier 2009: 201)

Suffix	Derivation	Category
-ième	*deux (2)* ⟶ *deuxième* ('second' ordinal)	Adj
-ième	*cinq (5)* ⟶ *cinquième* ('fifth' part)	Adj/N
-ain	*quatre (4)* ⟶ *quatrain* ('quatrain')	N
-aine	*douze (12)* ⟶ *douzaine* ('dozen')	N
-aire	*trente (30)* ⟶ *trentenaire* ('thirty-year-old')	Adj/N

2.3 Morphosyntactic category

Following Saulnier (2010), we consider simple cardinals to be a sub-category of indefinite determiners, CARD.

Saulnier (2010: 31–40) applies the discriminating contexts defined in Leeman (2004)'s work on French indefinite determiners. She shows that cardinals have the following distribution across the six diagnostic contexts.

(5) *en* dislocation: + ⟶ il a *deux* solutions = il en a *deux*
'he has 2 solutions = he has 2'
only alone before N: – ⟶ mes *deux* livres (*mes *plusieurs* livres)
'my 2 books (*my several books)'
following the indefinite: – ⟶ *un *deux* livres (un *certain* livre)
'*a 2 books (a certain book)'
following the definite: + ⟶ les *deux* livres (*les *certains* livres)
'the 2 books (*the certain books)'
followed by the definite: – ⟶ **deux* les livres (*tous* les livres)
'*2 the books (all the books)'
followed by *de* NP: + ⟶ *deux* de mes collègues
'2 of my colleagues'

With these criteria in mind for the category CARD, it becomes clear that there are simple cardinals that were not listed in (2) because they do not participate in the formation of complex cardinals.

Zéro '0', for example, is not a construction unit for complex cardinals but it behaves like a CARD in all the contexts in (5). Saulnier (2010: 38) considered *zéro* to depart from the cardinals distribution because she could not find examples for the contexts in (6), expecting *zéro* to be singular.[8]

[8] In the same contexts, Saulnier does not examine *un* and the surprising plural number that arises when it follows a definite or a possessive. For example, in *pour ses/son* ***un*** *mois* 'for his one month anniversary', the masculine singular form of the possessive *son* is far less common than the plural *ses*; the possessive can take its plural form *ses* despite the presence of the cardinal *un* '1'.

(6) Examples from the web (26/12/2016)

en dislocation: + ⟶ Il a des tas d'contacts, des tonnes de numéros pour remplir son phone mais des vrais potes il en a *zéro*.[9]

only alone before N: – ⟶ Et il ne nous restera alors que **nos**$_{\mathrm{pl}}$ *zéro* euros d'augmentation pour pouvoir demander un crédit.[10]

following the indefinite: – ⟶ *un *zéro* livre/livres.[11]

following the definite: + ⟶ Je vote pour **les**$_{\mathrm{pl}}$ *zéro* heures payées trente-cinq.[12]

followed by *de* NP: + ⟶ Mais même les potes des autres viennent ici et *zéro* **de mes potes** sont venus me voir.[13]

And contra Saulnier (2010), *zéro* also appears in *zéro*+N subject NPs:

zéro+N subject: + ⟶ Pendant ce temps, ***zéro* personnes**$_{\mathrm{pl}}$ sont mortes de surdoses de marijuana.[14]

In derivational morphology, *zéro* also gives a corresponding ordinal *zéroième* following the pattern of other simple cardinals.

2.4 Morphological output

Apart from fixed value cardinals, French uses variable cardinals such as *n* 'n' (pronounced [ɛn]) or *x* 'x' (pronounced [iks]). Like *zéro*, these variable cardinals do not participate in complex cardinal formation but they appear in the contexts in (5) and allow a subset of the derivations for fixed value cardinals (e.g. *énième* 'nth' pronounced [ɛnjɛm] and *xième* 'xth' pronounced [iksjɛm]).

(7) a. Une solution consiste à rechercher les *N* meilleures solutions pour chaque ville épelée.[15]

b. Donc l'installateur fait des bidouilles avec les *X* paramètres qui en [soi] ne sont pas très clairs ou pas forcément adaptés aux diverses situations des clients…[16]

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[9] 'He's got many contacts, tons of numbers to fill his phone, but real mates, he's got zero.' https://genius.com/Enz-narcisse-and-cassandre-lyrics

[10] 'Then we will only have our 0 euros of raise to ask for a credit.' http://psasochaux.reference-syndicale.fr/files/2015/04/Tract-avril-15.pdf

[11] '*a zero book/books'

[12] 'I'm voting for the 0 hours being paid as 35.' https://fr.toluna.com/opinions/762230/Etes-vous-pour-ou-contre-les-35-heures

[13] 'But while even the other guys' pals come here, 0 of mine have come to see me.' https://twitter.com/MisHyding/status/762360289329307649

[14] 'All this while, 0 persons have died of marijuana overdose.' https://anarchocommunismelibertaire.wordpress.com/

[15] 'A solution would be to search for the N best possibilities for every city name.' http://www.afcp-parole.org/spip.php?article152

[16] 'So the installer switches around the X parameters which are a bit obscure or not necessarily adapted to the various customer situations.' https://www.bricozone.fr/t/reglage-chaudiere-viessman.11296/page-7

c. Aujourd'hui, je constate que pour la *énième* fois, une voiture est garée devant mon entrée de garage, m'empêchant de sortir.[17]

These cardinals are obtained by converting letter names, usually French or Greek, to cardinals, making them the output of a morphological process and therefore fitting part of criterion (1e).

2.5 Open-ended set

In the general domain or in mathematical contexts this practice is limited to the conversion of a few letter names, but in computer programming names for integer-valued variables are created all the time and behave as simple cardinals , making CARD an open-ended category.[18] Even the derived ordinals appear in computer program descriptions.

(8) a. Lance le son à partir de la *nbième* [ɛnbejɛm] seconde.[19]
    b. appFunc(NUM): Renvoie l'adresse de la *NUMième* fonction de la page courante[20]

The preceding discussion shows that French simple cardinals are part of an open-ended set with the productive coinage of integer variables. As we have seen above, ordinal derivation takes simple cardinals as input and letter name conversion gives simple cardinals as output. These three observations indicate that French simple cardinals fit the property (1e).

2.6 Interim conclusion: the lexical status of simple cardinals

In this section, we have shown that simple cardinals in French have all the properties deemed characteristic of lexemes by Fradin (2003). Like typical lexemes, elements of CARD are created by borrowing and arbitrary coining while grammemes emerge through diachronic phenomena. Considering simple cardinals to be lexemes might seem at odds with the fact that we have taken them to be a sub-category of determiners, usually not regarded as a lexeme-based category. In the following section, we argue that CARD, in general, are a part of the syntactic category of determiners but constitute a morphological category of their own.

[17] 'Today, for the nth time, I see a car parked in front of my garage door, blocking my way.' https://goo.gl/lOrTuo

[18] Note that the French complex cardinals are not an open-ended set but rather a large set containing one trillion elements, as French speakers can count from 0 to 999,999,999,999.

[19] 'Run the soundbite from the nbth second.' http://www.forum-dessine.fr/index.php?id=06038

[20] 'Returns the address of the NUMth function in the current page.' https://goo.gl/LHh46c

3 French cardinals: Category?

In this section, we examine the status of French cardinals, simple and complex. We start with an overview of 'The Composition of Complex Cardinals' (Ionin & Matushansky 2006), as an example of a completely syntactic view of cardinal derivation. Then we argue that the phonological idiosyncrasies of complex cardinals are best modelled with a morpholexical system.

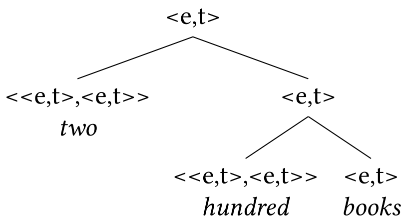
3.1 Complex cardinals in syntax

Ionin & Matushansky (2006: 316) argue that 'complex cardinals are composed entirely in syntax and interpreted by the regular rules of semantic composition'.

3.1.1 Semantics

Their analysis describes the semantics of complex cardinals and their syntax in several languages, focusing particularly on Russian. To allow for the semantic combination of Cards in CardP, they propose that simplex cardinals have the type <<e,t>, <e,t>> so that a series of simplex cardinal followed by a noun predicate of type <e,t> will be able to combine step by step with a parent simplex cardinal as in (9) and result in a type <e,t>.

(9)



The actual semantic combination is not described in detail but the authors seem to rely on the packing strategy of Hurford (2007) where complex cardinals are analyzed based on the simple set of syntagmatic rules associated with calculations in (10). Figure 1 gives the corresponding structure for 5,002,600.

(10)

- $\text{NUMBER} \longrightarrow \begin{Bmatrix} \text{DIGIT} \\ \text{PHRASE (NUMBER)} \end{Bmatrix}$

  value(NUMBER) = value(PHRASE) + value(NUMBER)

- PHRASE $\longrightarrow$ (NUMBER) M

  value(PHRASE) = value(NUMBER) × value(M)

Hurford describes the packing strategy as a constraint on the syntagmatic grammar in (10):

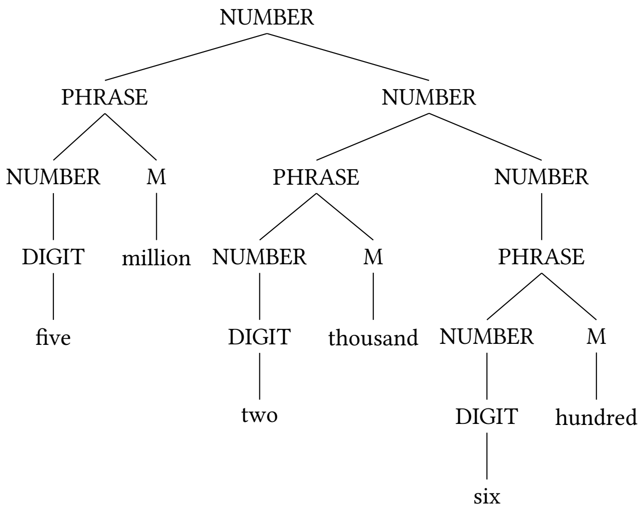


Figure 1: Syntagmatic analysis of 5,002,600 from Hurford (2007)

- The sister constituent of a NUMBER must have the highest possible value.[21]

The semantic analysis proposed by Ionin & Matushansky (2006) does not warrant a syntactic view of complex cardinals. From an external perspective, it manages to treat complex cardinals and simple cardinals in the same manner, giving them the same semantic type and the same combinatorial constraints on the counted noun (atomicity and countability).

3.1.2 Syntax

Concerning syntax, Ionin & Matushansky (2006) describe two phenomena relevant to French cardinals: case assignment and number morphology. In Russian, cardinal-containing NPs do not realize the direct cases (nominative & accusative) the same way as other NPs. For example, the NPs in (11) could all be used as subjects or direct objects. In (11a), *šag* ‘step’ has the nominative/accusative plural form expected for a direct argument but in (11b) it has the genitive singular form (paucal in the terms of Ionin & Matushansky) and, in (11c), the genitive plural form.

(11) a. šag-i
step-NOM.PL
‘steps’

b. četyre šag-á
four step-GEN.SG
‘four steps’

[21] This constraint is intended to have the same effect as converting time in seconds into complex units such as days/hours/minutes/seconds, maximising the number of days first, then hours, minutes and finally seconds.

c. šest' šag-ov
six step-GEN.PL
'six steps'

The case and number appearing on the head noun depend on the last simple cardinal in CardP. Cardinal 1 does not interfere with direct cases, cardinals 2–4 assign genitive singular and the other cardinals assign genitive plural.

This phenomenon also happens inside CardP in multiplicative contexts such as (12). *Tysjača* '1,000' appears in the nominative singular alone, but in the genitive singular with 4 and in the genitive plural with 5.

(12) a. tysjač-a šag-ov
thousand-NOM.SG step-GEN.PL
'one thousand steps'

b. četyre tysjač-i šag-ov
four thousand-GEN.SG step-GEN.PL
'four thousand steps'

c. pjat' tysjač šag-ov
five thousand.GEN.PL step-GEN.PL
'five thousand steps'

The form variations above do not interfere with the external case and number. The case and number realized internally on the head noun and the multiplied cardinals in the CardP do not affect the case and number of the NP in its relation to the rest of the sentence.

French does not have an inflectional case system similar to Russian but cardinals still display similar properties. In syntax, the CARD category identified for morphology in section 2.3 opposes the cardinals ending with elements *million* and *milliard*, infelicitous in (13a), with all other cardinals infelicitous in (13b).[22]

(13) a. Paul a deux/cent/*un million euros à la banque.
'Paul has X euros in his account.'

b. Paul a *deux/*cent/un million **d'**euros à la banque.
'Paul has X **of** euros in his account.'

The data in (13) could be interpreted as a difference in category, *un million* being considered as a noun rather than a CARD. But while the use of *un million* changes the shape of the NP, it does not affect its external relations to the sentence, just as in Russian. It appears that *millions* and *milliard* assign genitive plural to the head noun resulting in

[22]This could be contrived as *million* and *milliard* being classifiers but their behavior in complex numerals shows that they are indeed cardinal construction elements.

(i) un milliard trois cents millions **d'**euros '1,300,000,000 euros'

(ii) un_{M} million une_{F} $pages_{F}$ '1,000,001 pages' a *de* NP without changing the overall distribution of the cardinal-containing NP. Both structures participate in the contexts (5) used by Saulnier (2010) repeated below.

(14) *en* dislocation: + ⟶ il en a *deux*/*un million*
'he has 2/1,000,000'
only alone before N: - ⟶ mes *deux* livres/mes *un million* de livres
'my 2/1,000,000 books'
following the definite: + ⟶ les *deux* livres/les *un million* de livres
'the 2/1,000,000 books'
followed by *de* NP: + ⟶ *deux*/*un million* de mes collègues
'2 /1,000,000 of my colleagues'

Including *million*, *milliard* and their combinations in the CARD category with different controlling features captures the external similarity while retaining the appropriate contrast between the different NP structures CARD N vs CARD *de* N in the examples above.

French also displays number morphology inside complex cardinals , like Russian. The marks are visible in liaison contexts before triggers as shown in (15).

(15) a. *cent* ans
sɑ̃t ɑ̃
'one hundred years'

b. deux *cents* ans
dø *sɑ̃z* ɑ̃
'two hundred years'

c. *vingt* ans
vɛ̃t ɑ̃
'twenty years'

d. quatre -*vingts* ans
katʁə -*vɛ̃z* ɑ̃
'eighty years'

The ⊕ forms of simple cardinals *cent* and *vingt* end in t but their final consonant is replaced by z in multiplicative contexts.[23] This change does not seem to be mandated by plural marking as *cent* and *vingt* are already plural controllers.[24]

All in all, Ionin & Matushansky (2006) and Hurford (2007) provide an interesting framework in which to analyze French cardinals as a unique syntactic category. The differentiated control properties and the idiosyncrasic number morphology they propose

[23]In liaison contexts, the t-final ⊕ forms alternate with the ⊖ forms depending on collocations. Frequent ones such as *vingt ans* '20 years' and *cent ans* '100 years' are generally pronounced with ⊕ forms (vɛ̃t⊕ɑ̃, sɑ̃t⊕ɑ̃), but rarer collocations like *vingt écureuils* '20 squirrels' and *cent écureuils* '100 squirrels' are often found with the ⊘ forms (vɛ̃⊘ekyʁœj, sɑ̃⊘ekyʁœj). But in any case, the emergence of a z-final ⊕ form outside multiplicative contexts is considered faulty: *vɛ̃z⊕ekyʁœj, *sɑ̃z⊕ekyʁœj.

[24]Hurford (2003: Section 3) describes a case in Finnish were number marking on cardinals makes a difference. Plural cardinals count groups of N while singular cardinals count N individuals.

allows for a uniform syntactic analysis where all complex cardinals are constructed in the same way. However, the phonological aspects of French cardinals do not go along with the perfectly predictable semantics and syntax of the complex cardinals on which Ionin & Matushansky (2006) build their syntactic view of the process.

3.2 Complex cardinals and phonology

From a phonological standpoint, idiosyncrasies are everywhere in the construction of French complex cardinals. In the following we review the various combinatorial exceptions in the formation of complex cardinals and argue that it would be difficult to account for these with a purely syntactic analysis.

As we have seen in section 2.1, French simple cardinals are subject to form variation according to liaison contexts. In the derivation of complex cardinals, however, simple cardinals use the same forms but in quite different distributions. For example, *vingt* '20' and *cent* '100' belong to the same type B in Table 1, p. 22: both combine with simple cardinals 2–9, but *vingt* uses the ⊕ form vɛ̃t[25] even though these cardinals are not liaison triggers, while *cent* uses the ⊖ form sɑ̃ in the same context, as shown in Table 3.

Table 3: *vingt* and *cent* combinations with simple cardinals from 2 to 9

	2	3	4	5	6	7	8	9
20⊕	vɛ̃t-dø	vɛ̃t-tʁwa	vɛ̃t-katʁ	vɛ̃t-sɛ̃k	vɛ̃t-sis	vɛ̃t-sɛt	vɛ̃t-ɥit	vɛ̃t-nœf
100⊖	sɑ̃-dø	sɑ̃-tʁwa	sɑ̃-katʁ	sɑ̃-sɛ̃k	sɑ̃-sis	sɑ̃-sɛt	sɑ̃-ɥit	sɑ̃-nœf

Combinations involving *cinq* '5' and *huit* '8' in the construction of multiples of 100 and 1000 are not parallel even though they belong to the same type D of simple cardinals in Table 1, with two alternating realisations for the ⊖ form: sɛ̃/sɛ̃k , ɥi/ɥit. With *cinq* both of the ⊖ forms can be used in the combinations but with *huit* only the short ⊖ form ɥi is felicitous:

(16) a. 500 sɛ̃-sɑ̃/sɛ̃k-sɑ̃ , 5000 sɛ̃-mil/sɛ̃k-mil
b. 800 ɥi-sɑ̃/*ɥit-sɑ̃ , 5000 ɥi-mil/*ɥit-mil

Moreover, the same simple cardinal *dix* '10' combines with 7–9 and with 1000, none of which are liaison triggers, but it uses the ⊕ form in the first case and the ⊖ in the second:

(17) a. 17 diz-sɛt , 18 diz-ɥit , 19 diz-nœf
b. 10000 di-mil

Finally, instances of *quatre-vingt* have to be pronounced with an r at the end of *quatre*, even for speakers who usually drop it in word-final complex codas.

[25]Note that this holds true independently of the fact that the ⊘ form of 20 is subject to diatopic variation between vɛ̃ and vɛ̃t .

(18) a. un arbre frappé par la foudre
œ̃n aʁbʁə fʁape paʁ la fudʁə = œ̃n aʁb fʁape paʁ la fud

b. vingt-quatre francs
vɛ̃tkatʁə fʁɑ̃ = vɛ̃tkat fʁɑ̃

c. quatre-vingts francs
katʁəvɛ̃ fʁɑ̃ ≠ *katvɛ̃ fʁɑ̃[26]

We conclude that even though both the semantic and syntactic dimensions of complex cardinal formation are simple and regular, the combinatory principles at work at the phonological level are far from simple and must be specific to cardinal formation, leading us away from syntax and towards a lexical account of the derivation of complex cardinals.

3.3 Complex cardinals in CARD

As complex cardinals have the same distribution in the Saulnier-Leeman contexts in (5) and serve as input for the ordinal derivation, we analyze numerical cardinals as compounds created by means of a phrase structure grammar similar to those proposed by Hurford (1975, 1994, 2003, 2007). The analysis will be presented in two parts. We first introduce a model limited to the structure of 2-digit cardinals where most of the phonological and syntagmatic idiosyncrasies occur and then generalize it to the rest of the cardinals.

3.3.1 2-digit cardinals

Cardinal components are categorized according to their combinatorial properties (Table 4). To demonstrate the mechanics of the analysis, we use arbitrary categories rather than motivated features to differentiate elements. The category names reflect their purpose in the system. Unit categories start with u for digits (u, u1, u4, u7) and uv (uv, uv1) for units under 20, while categories for multiples of ten begin with d (d, d1, d2, d6).[27]

The rules in Table 5 generate all 2-digit cardinals (category Digit2). Rule 1 states that simple cardinals are de facto Digit2. Rule 2 generates *dix-sept*, *dix-huit*, *dix-neuf*. Rules 3 and 5 assemble *et un* and *et onze*. Rule 4 produces DixP for number between *vingt* '20' and *cinquante-neuf* '59'.[28] Rule 6 makes the *soixante* compounds from *soixante* '60' to *soixante-dix-neuf* '79' and rules 7 to 9 create the compounds based on *quatre-vingt* for number between *quatre-vingts* '80' and *quatre-vingt-dix-neuf* '99'.[29] Finally, rule 10 elevates all intermediary compounds to Digit2.

[26]katvɛ̃ is correct, however, for the decimal number '4.20'.

[27]To account for the Swiss and Belgian cardinal systems, the category d would have to include *septante* '70', *octante/huitante* '80' and *nonante* '90'.

[28]In rule 4, the ⊕ form is selected for the first term: d2.⊕=vɛ̃+t

[29]In rule 7, the ⊖ form is selected for the first term, Dix8X.⊖=katʁəvɛ̃. In rule 9, The liaison consonant for d2 changes to z, ⊕ becomes vɛ̃+z.

Table 4: Categories of cardinal components for 2-digit cardinals

Cat	Components	Example	
u	deux (2), trois (3), cinq (5), six (6)	vingt-**deux**	20+**2**=22
u1	un (1)	vingt-et-**un**	20&**1**=21
u4	quatre (4)	**quatre**-vingts	**4**x20=80
u7	sept (7), huit (8), neuf (9)	dix-**sept**	10+**7**=17
uv	douze (12), treize (13), quatorze (14) quinze (15), seize (16)	soixante-**douze**	60+**12**=72
uv1	onze (11)	soixante-et-**onze**	60&**11**=71
d	trente (30), quarante (40), cinquante (50)	**trente**-deux	**30**+2=32
d1	dix (10)	***dix**-deux≠douze	**10**+2≠12
		soixante-**dix**	60+**10**=70
d2	vingt (20)	quatre-**vingts**	4x**20**=80
d6	soixante (60)	**soixante**-treize	**60**+13=73
et	et (&)	trente-**et**-un	30**&**1=31

Table 5: Syntagmatic rules for 2-digit cardinals

	Rule	Comment
1	Digit2 ⟶ u/u1/u4/u7/uv/uv1/d/d1/d2/d6	simplex cardinals
2	Dix1P ⟶ d1.⊕ u7	diz (10) for 10+7..9
3	Et1 ⟶ et u1	eœ̃ (&1) for 20/30/40/50&1
4	DixP ⟶ d/d2.⊕ u/u4/u7/Et1	20/30/40/50+2..9/&1
5	Et11 ⟶ et u1/uv1	eœ̃/eɔ̃z (&1/&11) for 60&1/11
6	DixP ⟶ d6 u/u4/u7/d1/Et11/uv/Dix1P	60+2..10/12..16/(10+7..9)/&(1/11)
7	Dix8X ⟶ u4 d2.z	4x20 for 80
8	DixP ⟶ Dix8X	complex 80
9	DixP ⟶ Dix8X.⊖ u/u1/u4/u7/d1/uv/uv1/Dix1P	80+1..16/(10+7..9)
10	Digit2 ⟶ DixP	complex cardinals

The syntagmatic rules in Table 5 integrate constraints stipulating the combining forms:

(19) a. Rules 2 and 4 use the linking form ⊕ of the first component;
b. Rule 7 changes the liaison consonant of the second component from t to z;
c. Rule 9 uses the ⊖ form of the first component.

Figure 2 illustrates the application of rules 1–4, and more particularly the way diz-sɛt and vɛ̃t-sɛt are obtained with d1.⊕ diz and d2.⊕ vɛ̃t .

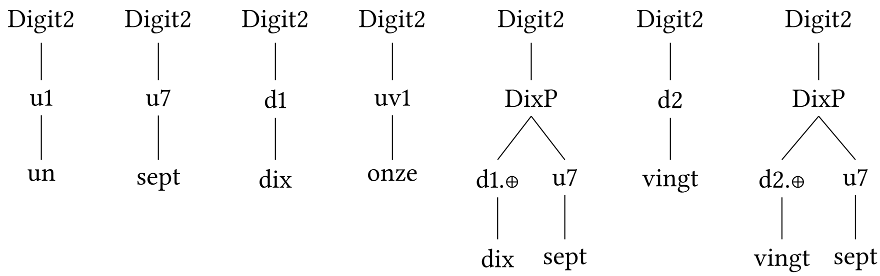


Figure 2: Phrase structures for 1, 7, 10, 11, 17, 20, 27

Figure 3 shows how *et onze* '& 11' and intermediary compounds such as *dix-sept* '17' are combined with *soixante* '60'.

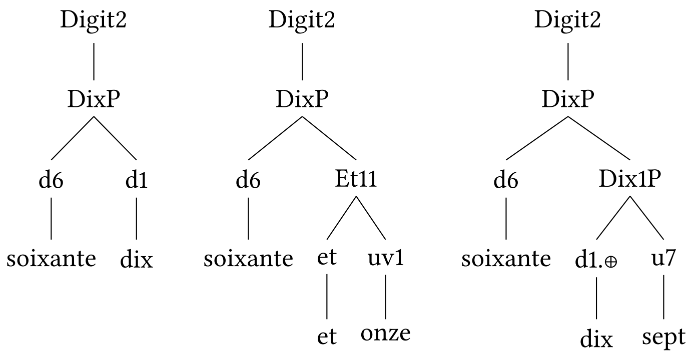


Figure 3: Phrase structures for 70, 71, 77

Finally, Figure 4 displays the combinations involving the *quatre-vingt* intermediary compound. When Dix8X is formed, the linking consonant of *vingt* is changed from t to z, but when the Dix8X is itself combined with another element by means of rule 9, its ⊖ form is selected rendering the previous change invisible. Thus we obtain the ⊕ form katʁə-vɛ̃z for *quatre-vingts* '80' and the forms katʁə-vɛ̃-sɛt and katʁə-vɛ̃-diz-sɛt for *quatre-vingt-sept* '87' and *quatre-vingt-dix-sept* '97'.

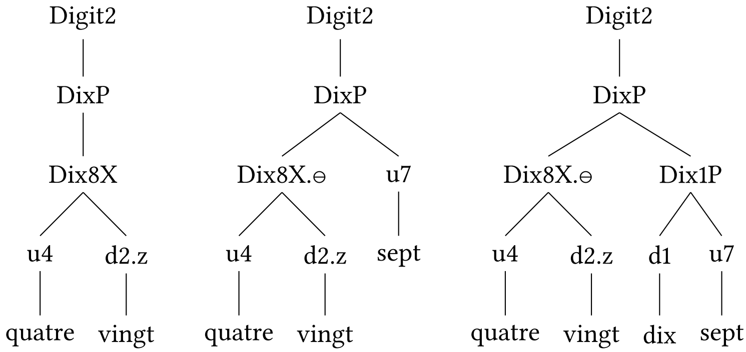


Figure 4: Phrase structures for 80, 87, 97

Even though we provide rules for all Digit2 cardinals in Table 5, most of these compounds are probably lexicalized. The rules are like redundancy generalizations *à la* Lieber (1982) or Koenig (1999), stating observable regularities in existing lexemes.

3.3.2 Numerical cardinals

With most of the idiosyncrasies residing below 100, the fragment in Table 6[30] for the composition of the higher combinations is simpler. It breaks the compounding into four levels corresponding to the counting units *cent* '100', *mille* '1,000', *million* 'million', and *milliard* 'billion'. Each level is composed of two rules, one to multiply the unit level and one to add the units from the level below.

Table 6: Syntagmatic rules for 3-digit+ cardinals

	Rule	Comment
11	CentX ⟶ u/u4/u7.⊖ Cent.z	hundreds
12	CentP ⟶ CentX/Cent.⊖ (Digit2)	adding the Digit2
13	MilleX ⟶ CentP/Digit2P.⊖ Mille	thousands
14	MilleP ⟶ MilleX/Mille (CentP/Digit2)	adding the hundreds
15	MionX ⟶ CentP/Digit2.⊖ Mion.z	millions
16	MionP ⟶ MionX.⊖ (MilleP)	adding the thousands
17	MiardX ⟶ CentP/Digit2.⊖ Miard.z	billions
18	MiardP ⟶ MiardX.⊖ (MionP)	adding the millions

For example, rule 11 assembles the multiples of *cent* '100' and rule 12 adds the units

[30] We found no critical data for or against adding a linking z to the ⊕ form of multiplied *million* and *milliard*, rules 15 and 17.

from the level Digit2.[31] In rules 12, 16 and 18, the selection of the ⊖ form[32] happens only in the presence of the optional second term.

Figure 5 shows how the two sets of rules combine in the analysis of numerical cardinals in general.

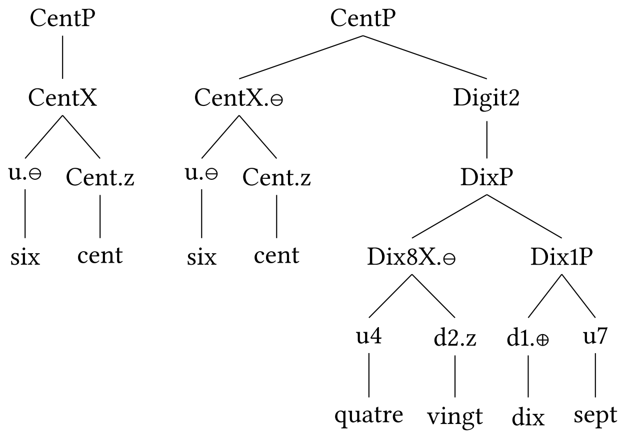


Figure 5: Phrase structure for 600 and 697

The analysis presented here relies on 26 combination elements, the 23 in (2) plus *et*, *million* and *milliard*. All numerical cardinals, including the simple ones, are derived from these elements. So, on the one hand, cardinal elements belong to special categories in the lexicon while, on the other hand, all numerical cardinals, including the simple ones, are CARDs derived from cardinal elements.

4 French cardinals: Paradigm?

In this section, we propose an analysis for a uniform paradigm of simple and complex cardinals. The analysis combines the observations about gender, liaison and compounding to (i) give a set of rules that fills the cells of the paradigm with the appropriate forms and (ii) associate each numerical cardinal with its proper syntactic frame.

As lexemes belonging to the CARD category, French cardinals, simple and complex, undergo inflection with a paradigm based on two features:

- LIAISON: ⊖, ⊘, ⊕
- GENDER: M, F

[31] These two rules could be modified to generate the 11 to 19 multiples of *cent* (e.g. *dix-huit cents* '1,800'). The rest would also have to be adapted to avoid the generation of aberrations such as **un million dix-huit cents mille* '2,800,000'.

[32] To be more precise, rules 16 and 18 select the M.⊖ form (i.e œ̃ for *un*).

This results in the six-cell paradigm exemplified in Table 7 with simple cardinals.

Table 7: Uniform paradigm of cardinals

'1'	M	F	'2'	M	F	'4'	M	F	'6'	M	F
⊖	œ̃	yn	⊖	dø	dø	⊖	katʁ	katʁ	⊖	si	si
⊘	œ̃	yn	⊘	dø	dø	⊘	katʁ	katʁ	⊘	sis	sis
⊕	œ̃n	yn	⊕	døz	døz	⊕	katʁ	katʁ	⊕	siz	siz

The paradigm of complex cardinals follows the pattern of the rightmost element in the compound. For example, in Table 8, TRENTE-ET-UN, QUATRE-VINGT-UN and CENT-UN share the pattern of UN, and TRENTE-SIX, QUATRE-VINGT-SIX and CENT-SIX inflect like SIX.

The only exception are *vingt* '20' and *cent* '100', which change their linking consonant from t to z in rules 7 and 11 (p. 32 & p. 34).

Not only do the forms of complex cardinals depend on the element on the right edge, but their controlling properties are also derived from the right edge element. This distin-

Table 8: Inflection on the Right Edge

'31'	M	F	'81'	M	F	'101'	M	F
⊖	tʁɑ̃teœ̃	tʁɑ̃teyn	⊖	katʁəvɛ̃œ̃	katʁəvɛ̃yn	⊖	sɑ̃œ̃	sɑ̃yn
⊘	tʁɑ̃teœ̃	tʁɑ̃teyn	⊘	katʁəvɛ̃œ̃	katʁəvɛ̃yn	⊘	sɑ̃œ̃	sɑ̃yn
⊕	tʁɑ̃teœ̃n	tʁɑ̃teyn	⊕	katʁəvɛ̃œ̃n	katʁəvɛ̃yn	⊕	sɑ̃œ̃n	sɑ̃yn
'36'	M	F	'86'	M	F	'106'	M	F
⊖	tʁɑ̃tsi	tʁɑ̃tsi	⊖	katʁəvɛ̃si	katʁəvɛ̃si	⊖	sɑ̃si	sɑ̃si
⊘	tʁɑ̃tsis	tʁɑ̃tsis	⊘	katʁəvɛ̃sis	katʁəvɛ̃sis	⊘	sɑ̃sis	sɑ̃sis
⊕	tʁɑ̃tsiz	tʁɑ̃tsiz	⊕	katʁəvɛ̃siz	katʁəvɛ̃siz	⊕	sɑ̃siz	sɑ̃siz

Table 9: Number morphology on the Right Edge

20	M	F	80	M	F
⊖	vɛ̃	vɛ̃	⊖	katʁəvɛ̃	katʁəvɛ̃
⊘	vɛ̃	vɛ̃	⊘	katʁəvɛ̃	katʁəvɛ̃
⊕	vɛ̃t	vɛ̃t	⊕	katʁəvɛ̃z	katʁəvɛ̃z
100	M	F	200	M	F
⊖	sɑ̃	sɑ̃	⊖	døsɑ̃	døsɑ̃
⊘	sɑ̃	sɑ̃	⊘	døsɑ̃	døsɑ̃
⊕	sɑ̃t	sɑ̃t	⊕	døsɑ̃z	døsɑ̃z

guishes cardinals ending in *million/milliard* from the others as seen below in (20) and in (13) (p. 28).

(20) a. un milliard trois cents millions cinq cent *mille* chinois/*de chinois
‘1,300,500,000 Chinese’

b. un milliard trois cent *millions* *chinois/de chinois
‘1,300,000,000 Chinese’

Cardinals ending with *million* ‘million’ or *milliard* ‘billion’ impose a *de*-NP structure. We use a DE feature to encode this difference: DE = + for (20b), DE = − for (20a).

Both the DE feature and the inflectional paradigm of compound cardinals can be constructed using the Right Edge mechanism introduced by Tseng (2003) and Bonami et al. (2004) to model French phrasal affixes (*à* ‘at’, *de* ‘of’) and liaison. The proposed mechanism ensures that the properties of the rightmost element are propagated to the top of the construction by copying the relevant features of the last component to its parent node at every level of compounding represented by the arrows in Figure 6. Rules combining two elements get a specific form from the left paradigm and prefix it to the paradigm on the right.

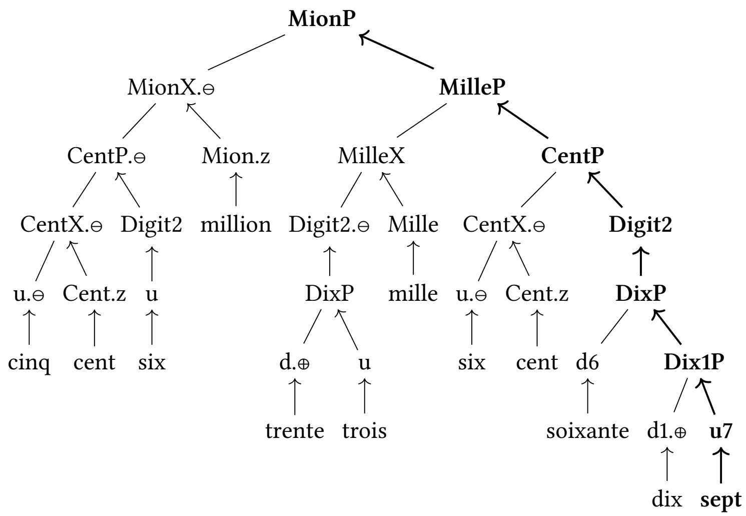


Figure 6: Phrase structure for 506,033,677

For example, on the right side, in (20a), the Dix1P prefixes the M.⊕ form of DIX diz to all forms of SEPT and carries the controlling property DE = − from SEPT. In (20b), the combination selects the M.⊖ form of SIX si and combines it with the modified paradigm of CENT where the linking consonant of the ⊕ forms t has been changed to z .

(21) a.

'10'

	M	F
⊖	di	di
⊘	dis	dis
⊕	**diz**	diz

DE = −

'7'

	M	F
⊖	*sɛt*	*sɛt*
⊘	*sɛt*	*sɛt*
⊕	*sɛt*	*sɛt*

DE = −

⟶

'17'

	M	F
⊖	dizsɛt	dizsɛt
⊘	dizsɛt	dizsɛt
⊕	dizsɛt	dizsɛt

DE = −

b.

'6'

	M	F
⊖	**si**	si
⊘	sis	sis
⊕	siz	siz

DE = −

'100'

	M	F
⊖	*sɑ̃*	*sɑ̃*
⊘	*sɑ̃*	*sɑ̃*
⊕	*sɑ̃z*	*sɑ̃z*

DE = −

⟶

'600'

	M	F
⊖	sisɑ̃	sisɑ̃
⊘	sisɑ̃	sisɑ̃
⊕	sisɑ̃z	sisɑ̃z

DE = −

The percolations proceed level by level, and yield a structure at the top with a full paradigm and the appropriate value of the DE feature.[33]

The model outlined here relies on the propagation of ready-made elementary paradigms via a phrase structure grammar rather than rules of exponence or referral based on the inflectional features of the different cardinals as is common with Word and Paradigm syntagmatic frameworks[34] such as A-Morphous Morphology (Anderson 1992), Paradigm Function Morphology (Stump 2001) or the Information-Based Model of Bonami & Crysmann (2013). It is more in line with paradigm-oriented models like Network Morphology (Corbett & Fraser 1993).

5 Conclusion

In this chapter, we set out to discuss the place of cardinals in French morphology with a focus on their status as lexemes, their categories and their inflectional paradigms. Taking into account the number of phonological idiosyncrasies in the formation of French cardinals, we argued that they should be considered as lexemes. Following Saulnier (2008, 2010), Fradin & Saulnier (2009), we examined both their morphotactic properties and their syntactic distribution and concluded that they belonged to a morphosyntactic category CARD inside the determiners. We showed that there are two types of cardinals regarding the way they associate with nouns, the direct type like CINQUANTE-DEUX (*cinquante-deux années*) and the indirect type like UN-MILLIARD-TROIS-CENTS-MILLIONS (*un milliard trois cents millions d'années*). This distinction making no difference on the

[33] '506,033,677'

	M	F
⊖	sɛ̃ksɑ̃similjɔ̃trɑ̃ttʁwamilsisɑ̃swasɑ̃tdizsɛt	sɛ̃ksɑ̃similjɔ̃trɑ̃ttʁwamilsisɑ̃swasɑ̃tdizsɛt
⊘	sɛ̃ksɑ̃similjɔ̃trɑ̃ttʁwamilsisɑ̃swasɑ̃tdizsɛt	sɛ̃ksɑ̃similjɔ̃trɑ̃ttʁwamilsisɑ̃swasɑ̃tdizsɛt
⊕	sɛ̃ksɑ̃similjɔ̃trɑ̃ttʁwamilsisɑ̃swasɑ̃tdizsɛt	sɛ̃ksɑ̃similjɔ̃trɑ̃ttʁwamilsisɑ̃swasɑ̃tdizsɛt

DE = −

[34] See Boyé & Schalchli (2016) for a typology of views on inflectional paradigms in different theories.

outside of the NP, we analyzed them as compounds based on 26 simple elements[35] using a phrase structure grammar, even though the cardinals below 100 are probably lexicalized. Our compounding mechanism propagates the inflectional and syntactic properties of the rightmost component to the entire compound to create its paradigm and percolate its type (DE = ±).

The type of compounds we advocate for is different from the usual two-component ones. It expands the ternary compounds described in the biomedical domain by Namer (2005) to higher levels of composition. The extended compounding mechanism allows to generate all numerical cardinals as CARD without having to cast them into the different subcategories that would be needed to break the compounding process into binary operations. It does not presuppose that complex cardinals are lexicalised but only that they can be created online by morphology, as [+morphological, -lexical] compounds in the sense of Gaeta & Ricca (2009).

The model outlined here should be integrated with the formal analysis of Bonami et al. (2004) of liaison in HPSG (Pollard & Sag 1994). It would be interesting to examine data from the cardinals in other languages to parallel the work of Stump (2010) on the ordinals[36] and from the composition of the decimals and its interference with the integers.[37]

5.1 Remaining questions

Cardinal coordinations do not respect lexical integrity. Examples like (21a) are common, and even stranger coordinations appear with ordinals where the first ordinal is realised as a gender-agreeing cardinal as in (21b).

(21) a. Quelques *soixante-dix* ou *quatre-vingt* mille personnages sont passés à la trappe, 35 000 sont à l'ombre.[38]

b. Ses débuts, il les fit, dans sa ville natale, au début du siècle dernier dans sa vingt-et-*une* ou vingt-deux*ième* année.[39]

Saulnier (2008) observes that *quelques* follows the syntactic distribution of CARDs and derives the *quelquième* ordinal found in *trente et quelquième* 'thirty-somethingth'.[40]

[35] Nothing would prevent French from using more elements. In fact, it has been proposed since the 15th century to expand the counting system by including *billion*, *trillion*, *quadrillion*, etc. (see Saulnier 2010: 147–151 for an overview of the proposals).

[36] French ordinals are derived from their cardinal counterparts by *-ième* suffixation as proposed by Stump (2010: p. 228) with the notable exceptions of *millionième* and *milliardième* which drop the *un* from *un million* and *un milliard*.

[37] Many ill-formed cardinals are in fact well-formed decimals. For example, *cinq vingt* is automatically understood as '5.20'. Furthermore, *un million un* '1,000,001', when not followed by a counted noun, is usually perceived as '1,100,000' with *million* interpreted as a measure unit.

[38] 'Some seventy or eighty thousand persons have disappeared, 35,000 are in jail.'
http://plumenclume.org/blog/173-erdogan-consolide-son-emprise-par-israel-adam-shamir

[39] 'His debut, he made at the beginning of last century, when he was in his twenty-first or twenty-second year.'
http://www.www.dutempsdescerisesauxfeuillesmortes.net/fiches_bio/darbon/darbon.htm

[40] Fradin & Saulnier (2009) also mention *combien/combientième* 'how many', *quel/quellième* 'which' as potential cardinal/ordinal pairs (*quantième/tantième* look more like fractions than ordinals).

The arguments developed in this chapter for a morphological analysis of the composition of cardinals rely on the idiosyncrasies of complex cardinals below 100. To capture the phenomenon in (21), it would be possible to propose a morphological analysis of lower complex cardinals as compounds and lexemes, while still allowing syntactic composition for higher complex cardinals.

Acknowledgements

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