Rule and order

Acquiring ordinals in Dutch and English

Meyer, C.M.

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Acquiring ordinals in Dutch and English

Using novel comparative acquisition data (from a total of 250 children aged 2;08–6;04), this first book on ordinal learning presents an acquisition pattern that is unlike any other. At first sight, the data seem straightforward: both learners of Dutch and English acquire irregular ordinal numerals (such as Dutch derde ‘third’ or English second) after regular ones (such as vierde ‘fourth’ and seventh), and even after analytic ordinal forms (hoofdstuk vijf ‘chapter five’). This holds for both comprehension and production.

What makes this process crucially different from familiar patterns in numerical and morphological development is that there is no evidence for an initial lexical learning stage. Children acquire the first cardinals (one, two, three, four) sequentially before they can count productively. In morphological development, productive rules usually follow storage of individual forms. In the ordinal case, however, children start out with a rule (informally: cardinal + suffix = ordinal, or for analytic forms: cardinal after a noun = ordinal). Though exceptions are acquired lexically, they come in after overgeneralization errors, rather than before; ordinal acquisition is not u-shaped.

The main claim is that children use morphosyntactic structure to acquire ordinal meaning. By combining insights from linguistics, developmental psychology and numerical cognition, this work not only provides an account for how linguistic rules can be the driving force behind ordinal acquisition, but also for why ordinals are so different in the first place. Put simply, not all rule-learning is equal, in part because not all storage is equal.
Rule and order

Acquiring ordinals in Dutch and English
RULE AND ORDER
ACQUIRING ORDINALS IN DUTCH AND ENGLISH

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Promotores: prof. dr. F.P. Weerman Universiteit van Amsterdam
prof. dr. L.C.J. Barbiers Universiteit Leiden
Copromotor: prof. dr. J.E.C.V. Rooryck Universiteit Leiden

Overige leden: dr. J. Don Universiteit van Amsterdam
prof. dr. H.J. Honing Universiteit van Amsterdam
prof. dr. A.C.J. Hulk Universiteit van Amsterdam
prof. dr. J.L. Lidz University of Maryland
prof. dr. J.C. Schaeffer Universiteit van Amsterdam
prof. dr. P. Schulz Goethe-Universität Frankfurt

Faculteit der Geesteswetenschappen

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So if there’s one thing I’ve learned from the past few years, it’s that sitting is extremely hard, and that I’m actually fairly bad at it. This is unfortunate, because as it turns out, writing a dissertation requires lots of extensive sitting to happen. (I guess that’s three things, but who’s into counting anyway?)

Of course, everybody knew this except me, much like everybody but me knew that I would eventually finish this thing, and that I would not quit, nor get fired. Many thanks to all of you, for humoring me along the way, graciously nodding and bringing me food and beverages, laughter, and a plethora of random things, as I rambled and even as I tried to convince you that you were wrong. Sorry for being so stubborn. However, without you, I might have been right, and in that sense, this book is a group achievement. So please let me take this moment to say thank you to you all. It’s hard to mention everyone individually by name, and I’m sorry if you cannot find yours below. If you’re looking for it, it should probably be there, and you should definitely yell at me later if it’s not. Since brevity is not my strong suit, I’d say CTRL+F is your friend here.

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¹ Sorry to the 2.5% of men in the Netherlands (see voornamenbank.nl), including some famous Jan’s in linguistics, who I may have just insulted. And especially sorry and thanks to Jan Rock, who shared/shares his child’s ‘driele’s ‘threeth’s’ and other language learning adventures. It’s always fun and encouraging to listen to your observations and your thoughts.
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Chapter I: Introduction and Chapter V: Discussion
Caitlin Meyer is the sole author of these chapters. These chapters have not been submitted for publication elsewhere.

Chapter II: Comparing cardinal and ordinal acquisition
Adapted slightly from: Meyer, Caitlin, Sjef Barbiers & Fred Weerman (2018). Ordinals are not as easy as one, two, three: the acquisition of cardinals and ordinals in Dutch. Language Acquisition. DOI: 10.1080/10489223.2017.1391266

Meyer, Barbiers and Weerman posed the research question whether the pattern and timing of ordinal acquisition differs from that of cardinals, and if so, whether these differences can be related to linguistic factors. With valuable input from Barbiers and Weerman, Meyer designed and carried out an experimental study in the spirit of Wynn (1992) in order to answer this question. Meyer applied for approval from the Ethics Committee, recruited participants and ran the experiments. She also trained and supervised research assistants who scored the data. Meyer then processed the data and ran the statistical analyses, after which she wrote the first version of the text. This was discussed during several supervision meetings. On the basis of valuable feedback from Barbiers and Weerman, Meyer rewrote and revised the manuscript into its published form. She made minor changes to the text and formatting for the version printed here.

Chapter III: Comparing comprehension and production
Adapted slightly from: Meyer, Caitlin, Sjef Barbiers & Fred Weerman (submitted). Rules rule in Dutch L1 ordinal comprehension and production.

Meyer, Barbiers and Weerman formulated the question under investigation in this study: how does the development of ordinal production compare to the development of ordinal comprehension? In order to answer this question, Meyer adapted the materials and design
from the previous study and carried out two experiments in the spirit of Wynn (1992) and Chapter II. Barbiers & Weerman provided feedback on the final experimental setup. Meyer applied for approval from the Ethics Committee, recruited participants and ran the experiments. She also trained and supervised research assistants who scored the data. Meyer processed the data, carried out the statistical analyses, and wrote the first version of the text. This was discussed during several supervision meetings. On the basis of valuable feedback from Barbiers and Weerman, Meyer rewrote and revised the manuscript into its current form.

Chapter IV: Comparing Dutch and English

Meyer asked two questions. The first is whether ordinal acquisition follows a strictly rule-based pattern in other languages, or whether lexical learning plays a role. The second is whether transparent analytic ordinals (e.g., chapter three) are comprehended before more frequently and normally used synthetic ones (third car), even if those synthetic forms are irregular. She decided to investigate both Dutch and English. Meyer adapted the method and design from the previous chapters, applied for approval from the Ethics Committee and contacted dr. Jeffrey Lidz at the University of Maryland. She helped recruit participants through the University of Maryland Infant and Child Studies Consortium and at the Center for Young Children, and tested all participants. She also trained and supervised research assistants who helped score the data. Meyer then processed the data, carried out the statistical analyses, and wrote the first version of the text. This was discussed during several supervision meetings. Meyer rewrote and revised the manuscript on the basis of valuable feedback from Barbiers and Weerman, and two anonymous reviewers. A similar version is currently under review. Meyer made minor changes to the text and formatting for the version printed here.
Chapter I

Introduction

1. Starting with the end

Doing research typically implies a journey into the unknown, but of course the report of that journey does not have to be. So, before I go into why you might want to read this work in the first place, allow me to begin with the end in mind. This dissertation is about how children acquire different kinds of number words: cardinal numerals (such as one, two, three) and especially ordinal numerals (such as in the fourth chapter or chapter four).

The main finding put forward here is that children acquire irregular ordinal numerals (such as Dutch derde ‘third’ or English second) after regular ones (such as vierde ‘fourth’ and seventh), and even after analytic ordinal forms like pagina drie ‘page three’. This means two things. First, ordinal acquisition looks nothing like cardinal acquisition, which also begins much earlier. Second, when children acquire ordinal meaning, they do this first for forms that follow a rule (informally: cardinal + suffix = ordinal, or for the analytic cases: cardinal numeral after the noun = ordinal), and they acquire exceptions like second and third later on. This holds for Dutch and English, and for comprehension as well as production.

If you were a teacher or parent of a child who participated in this project, you might now be thinking I have simply stated the obvious: “But of course that’s what happens!” you respond. You might even tell me a funny anecdote about a child saying or correcting *driede ‘three–th’ or *two–th. I would naturally take note of it, as with the story in (1):

(1) A boy, aged 3;04, has just counted the dates in March 2016 as the *twoth, the *threeth, the fourth.

   Mother: So today is the twoth?
   Son: No! Tooth is in your mouth! Two-th [pausing before and emphasizing the suffix] is the number.

   (Maryland, March 2016)
Even without such examples, or perhaps even as a trained psychologist or linguist presented with these facts, your intuition might be that it only makes sense for children to prefer regular forms. We have known for years that children acquire morphological rules early and readily (cf. Marcus, Pinker, Ullman, Hollander, Rosen & Xu 1992; Wexler 1998; or e.g., Polišenská 2010 for discussion). This begs the question: what makes this news, and why should we spend time thinking about ordinal acquisition at all?

An easy answer might be that scientific study is more than a collection of anecdotes and intuitions on the basis of work on other phenomena, so ordinal acquisition deserves more than just that. But the real answer, I think, lies in taking another look at the findings presented here. Rather than thinking but of course, perhaps we should be asking but why. Why do children care more about rules in this scenario, and less about other factors we know play a role in language acquisition or numerical development? Take frequency, for example: derde ‘third’ is roughly fifteen times more frequent than negende ‘ninth’. If frequency is important, would we not expect derde ‘third’ to be acquired sooner than higher ordinals, and would we not expect the opposite (later acquisition) for something low-frequent like chapter four? Such forms should be especially tricky, given that they are more context-dependent than those of the fourth chapter type, and might also differ somewhat in meaning (see Chapter IV, no pun intended).¹

Moreover, if children are overgeneralizing rules, then why does the summary above mention nothing about a “U-shaped” or “change for the worse” pattern in development? The classic example of such a pattern is irregular past tense, where children initially say something like felt or ate correctly, then temporarily also make overgeneralization errors such as *feeled or *eated, before going back to only the target forms (e.g., Pinker 1999). The U-shape is not mentioned above for a very simple reason: there is no evidence for it; the first stage in the U-pattern is absent from ordinal acquisition.

¹ Here I mean context-dependent in the sense that the acceptability of analytic forms seems to vary per context. Most speakers I have consulted easily accept analytic ordinals in contexts where they function more like a title or a name: chapter four, page twenty, and week three (in the schedule of your Language Acquisition course), and perhaps candidate two (in the running for that teaching position) or suspect four in a police line-up are all fine, but time three the phone rang or car four in line at the traffic light may seem less natural to some.
All of these perspectives (frequency, form and use, changes for the worse) have been proposed for some linguistic phenomenon or another, and all would lead us to expect different outcomes for ordinal acquisition. Note that none of these points take into account that ordinal numerals may also rely on the development of numerical cognition and cardinality, such as learning that each cardinal refers to an exact quantity (and each ordinal to a specific individual) or that it matters in which order the numbers in a count list are recited. Should this not interact with ordinal acquisition? And how different is ordinal development from cardinal development, anyway? In short, perhaps these findings are more complex than we might be inclined to think initially, warranting a closer look at the topic at hand.

2. Ordinals and core knowledge of number

Despite what the preamble above might suggest, such an investigation actually starts with the last two questions posited in the previous paragraph: before we can even think about ordinals, it helps to understand more about cardinals first. Not only are most Dutch and English ordinals linguistically derived from cardinals (as the informal rule suggests), they are also conceptually related to them. Answering the question of how many requires much of the same knowledge as answering the question of which one in a row. In both cases, children need to recite the numerals in their count list in the correct order, using one numeral per item counted, without skipping any items or counting any items twice (Gelman & Gallistel 1978). However, though conceptually similar, the linguistic difference might have consequences for both the timing as well as the pattern of ordinal acquisition.

I would almost say that this is essentially the question put forward in Chapter II, and then move on to the next point, but that would not be doing the deeper problem much justice. To simply state that ordinals are derived from and are much like cardinals, and wonder whether that affects acquisition patterns, casually skips over the decades of research invested in numerical development, as if acquiring cardinals is some trivial thing that magically happens overnight. We should at least pause to think about the origins of that question and what it means for the present study. Without some basic idea of how numerical concepts develop in cardinals, it is impossible to productively think about what parts of that process
might realistically apply to the ordinal situation and how. Let me take a step back and elaborate on this for just a moment.

What does it mean to know what \textit{two thousand and eighteen} means? If anything, it means you are special. Though humans and animals alike are equipped with the cognitive means to represent numerical concepts, only humans can do so exactly and reliably for any given numerosity (Carey 2009; Dehaene 1997; Dehaene 2009; Spelke & Kinzler 2007). Many scholars account for the shared abilities between human adults and animals by assuming ‘core knowledge’ of number, arguing that there are two innate systems with which not just human adults, but also pre-linguistic infants and animals can represent numerical concepts. The first of these shared systems is the so-called \textit{Approximate Number System} (ANS), the second is the \textit{Object Tracking System} (OTS) — sometimes referred to as the \textit{parallel individuation system} (e.g., Le Corre & Carey 2007).

The ANS is employed for imprecise, non-symbolic, numerical representations of large magnitudes. It distinguishes numerosities of distinct sets by estimation, comparing the set sizes without individuating the members in that set. Because it does not individuate, it is not sensitive to adding or subtracting one (the successor function), so its discriminatory powers are ‘merely’ ratio-sensitive (to be precise: argued to be governed by Weber’s Law). This means the ANS only detects a difference in set size if that difference is large enough. That ratio starts out at 1:2 and becomes more sensitive with age; in some adults as sensitive as 10:11 (Dehaene 1997; Halberda & Feigenson 2008; Libertus & Brannon 2009; Lipton & Spelke 2003; Xu & Spelke 2000). Put differently, the ANS can distinguish between 1 and 2, between 4 and 8, eventually between 20 and 30, but never between 20 and 21. The OTS, on the other hand, is almost the mirror image: this system is sensitive to individuals, not ratios. It can detect addition or subtraction of one, and discriminate between both one and two, and two and three. However, infants (surprisingly) fail on discriminating one from four, as this system only allows for such exact representations of up to three or four individual objects (e.g., overviews in Feigenson, Dehaene & Spelke 2004; Spelke & Kinzler 2007). This means this system cannot distinguish between 20 and 21, either.

Clearly, neither of these systems could independently lead to an exact understanding of something like 4733. So how is it, given that we have an exact system for small numbers, and an inexact system for large numerosities, that adults can conceive of such a large number, such that
we also know it is exactly one more than 4732? What do infants develop (that animals lack) that would allow them to combine these two innate, non-species-specific systems of number? This brings us back to language.

Various scholars (most notably Carey 2009; Hurford 1987; Spelke 2011, 2017) have argued that language plays a critical role in overcoming the boundaries of these two individual systems and how children develop exact and adult-like concepts of number. Obviously, language is too vague; we want to know what aspects of language are responsible for connecting the ANS and OTS. Urgent as this issue may be, I will not go into any details here. For one, this question is at the center of an elaborate debate in the literature that has, at least to my understanding, not led to any definitive verdicts so far — the count list, quantifiers, grammatical number have all been argued to be relevant (see e.g., Carey 2009; Le Corre & Carey 2007; Spelke 2017 for overview and discussion). For another, the details of the underlying account are, for the present purposes, not as crucial as the robust empirical results this very productive line of research has revealed. These results, and their implications for ordinal learning, are discussed in Chapter II.

However, if we now quite generally assume (for the present purposes) that there is something special about language that plays a role, we might expect cross-linguistic differences in how cardinals are acquired. In addition, we could expect there to be effects of the core knowledge systems of number and (the interplay with) language outside the domain of cardinals, for example in the ordinal domain. This turns out to be a key issue in Chapters IV and V, but it is the starting point for Chapter II: understanding why numerical knowledge is interesting and how it develops, and how that relates to ordinal development. Specifically, I ask whether the pattern and timing of ordinal acquisition differs from that of cardinals, and if so, whether these differences are related to linguistic factors.

Chapter II should first convince you that developing an exact understanding of cardinals is universally slow and arduous. I describe, in detail, how cardinals are first acquired one by one before children are able to generalize their knowledge over an entire count list, and what non-linguistic knowledge is necessary to make using number words actually work. I also discuss literature that shows that the patterns attested for cardinal acquisition are cross-linguistically and cross-culturally robust, though the exact timing of the (stages within) these patterns shows a great amount of variation.
Having fleshed out the cardinal situation, we can then turn to ordinals, where we will quickly see that ordinal acquisition is poorly understood, or at least poorly documented. The past few decades have only produced a handful of findings, which is startlingly little given the lively investigation of the development of cardinals and cardinality, as well as the development of quantification in child language (see Lidz 2016 for an overview). This makes the first study discussed in this dissertation more exploratory in nature. I argue that Dutch is a prime candidate for this purpose, and then set out to systematically compare cardinal and ordinal acquisition in Dutch. To do so, I adapt the tried and true Give-a-Number paradigm used in work on numerical development (e.g., Wynn 1992) to fit the questions at hand, which is the methodological strategy used throughout the project as a whole.

The results of this first experiment not only show how different cardinal and ordinal acquisition proceed, but also suggest that whereas the language-specific differences do not affect the pattern of cardinal acquisition (whatever the role of language may be), the opposite might hold for ordinals. Because I find irregular ordinal *derde ‘third’ is acquired later than regular forms, I reason that (i) perhaps ordinals are acquired by means of a rule, and (ii) that the pattern in which given ordinals are acquired depends on the regularity of their morphological form. Put differently, the working hypothesis at this point is that language-specific factors do play a role in ordinal acquisition, because children rely on the regularity of the ordinal form to grasp ordinal meaning. The remaining empirical questions (and the goal of the rest of this work) should now follow fairly obviously: to what extent is there evidence for rule-based learning in the places we expect it, in the way that we expect it?

3. Rule and order

The first “where and how” is in ordinal production. Chapter III focuses on Dutch ordinal production in comparison to a slightly more elaborate investigation of comprehension. If it is the case that children make use of an ordinal rule, then we make the following predictions for comprehension and production. For comprehension, we predict that forms that are ungrammatical but derivable via the postulated rule, e.g., *driëde ‘third’, are interpretable when (grammatical) regular ordinals such as vierde ‘fourth’ are acquired. This should hold regardless of children’s
understanding of derde ‘third’. Put differently, children who can find the tweede ‘second, lit: two–th’ and the vierde ‘fourth’ and possibly even the zesde ‘sixth’ or negende ‘ninth’, but crucially not the derde ‘third’ in line, should be able to find the *driede ‘threeth’, as this form follows the rule. Moreover, we predict for production that this ungrammatical form is the preferred one, as overgeneralizations are typical in the acquisition of rules. Both of these predictions are borne out: children have no difficulty comprehending *driede ‘threeth’, and this form also occurs in their elicited production, even in children who do comprehend derde ‘third’.

This cannot be the whole story, however, since those who speak Dutch might note that we have skipped some complicating factors: (i) we have yet to mention anything about eerste ‘first’ (isn’t this an irregular ordinal, too?), (ii) Dutch has two ordinal suffixes to choose from (namely –de for most ordinals under twenty and –ste for all other ordinals), and (iii) what about ordinals of the chapter four variety mentioned earlier?

The first point is addressed in two stages, once in Chapter II and again in Chapter III. Following Barbiers (2007), the assumption throughout this project is that Dutch eerste ‘first’ (and later also English first) is not actually an ordinal, but a superlative (such as grootste ‘biggest’ or meeste ‘most’). This means that it is not derived from the numeral een ‘one’ but from the positive form eer ‘before’, and the corresponding comparative eer–der ‘before/sooner’ — at least in adult Dutch. Barbiers (2007) provides morphosyntactic evidence that shows erste ‘first’ is a superlative (see also Chapter II), and the findings here show that eerste ‘first’ is closer to a superlative in child Dutch as well. Chapters II and IV show that children comprehend erste ‘first’ before tweede ‘second’ or any other ordinals, though it comes in rather late for a superlative. Chapter III shows that overgeneralization errors such as *eende or *eenste are less frequent than *driede, despite the fact that *driede is never in the input, but *eende and *eenste are sometimes heard in larger ordinals: both honderdeneende and honderdeneenste ‘hundred and one–th/one–st’ occur. Instead of such ordinal overgeneralizations, children sometimes opt for (grammatical) superlative alternatives for erste ‘first’, saying e.g., voorste ‘frontmost’. In other words, erste ‘first’ may seem like an ordinal in the

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2 Note that the positive form eer ‘fore’ does not see much use in modern adult Dutch, and I certainly would not want to claim that children (or adults, for that matter) have to know (how to use) eer on its own in order to acquire erste ‘first’.
context of a count list, but the data show acquiring eerste ‘first’ is a different kind of challenge than acquiring tweede ‘second’ or derde ‘third’.

The second point (Dutch having two ordinal suffixes) is relevant for acquisition because it represents an extra challenge for the learner. Moreover, if we assume ordinals are acquired via a rule, the question arises whether the rule children postulate accommodates both suffixes from the start. Chapter III shows that while children have no difficulty understanding achtste ‘eighth’, which is the only ordinal under twenty to take –ste instead of –de, they have a hard time producing it, saying *acht–de (overgeneralizing the other suffix) instead. This type of error also seems to last longer than errors on derde ‘third’ (i.e., production of *driede ‘third’), even though achtste ‘eighth’ was easier to comprehend than derde ‘third’. I address the consequences for the rule in more detail in Chapter V.

The third point (what about ordinals of the chapter four variety) is one of the two main issues in Chapter IV. To be fair, I am well aware some readers may not be willing to consider chapter four an ordinal at all, or perhaps one that is limited to certain contexts only — like a title or a name. However, despite their markedness, these analytic ordinals (as opposed to synthetic ordinals, i.e., the fourth chapter type) very clearly show that it is not one specific rule that children use to acquire ordinals, but that they use the form to derive meaning. This is evident from the fact that none of these ‘weird’ ordinals pose a problem to the children who participated in this study: both Dutch learners and English learners comprehend the fourth car and car four equally well. Here, too, the regularity pays off: analytic ordinals for the third in line (auto drie and car three, respectively) elicit more correct responses than for their irregular synthetic counterparts (de derde auto and the third car, respectively). How children link the order of the cardinal and the noun to the correct numeric interpretation (numeral before the noun yields a cardinal reading, numeral after the noun an ordinal one) remains an open question — perhaps some Humboldtian (Vennemann 1992) or mutual exclusivity (e.g., Merriman & Bowman 1989) principle helps — but one thing is undeniable: when the relationship between the ordinal and the cardinal from which it is derived is transparent, the meaning of the ordinal is clear. **To be brief: structure is easy, meaning is hard, and children use the former to get to the latter.** After all, if children did not need the form, they would simply learn derde ‘third’ by rote (as they initially do with low cardinals).
One could say that the evidence for Dutch is essentially trivial, as derde ‘third’ is the only true exception in the ordinal count list (now that we have categorized eerste ‘first’ as a superlative). Perhaps a rule is not an attractive option for learners acquiring a count list that has more exceptions. English is an example of such a language (with exceptions second, third, and fifth) and so Chapter IV sets out to discover whether children acquiring English follow the same strategy as Dutch learners do. As I stated in one of the very first sentences, they do: children acquiring English comprehend regular ordinals more often than irregular ones, and some of them produced *two-th, *three-th or even *five-eth during the task. I do not know how to account for such data without postulating some sort of rule.

Perhaps you are still thinking of course: since adults obviously have a productive ordinal rule, surely children have one, too. But note that the claim here is not that children ultimately wind up with a rule — that would indeed be obvious. The claim is that children make use of this ordinal rule from the moment they begin to acquire ordinals. As I discuss throughout this work, but especially in Chapter V, this idea is not as straightforward as it seems. For one, this pattern is entirely unlike those we see elsewhere: it is unlike cardinal acquisition, and unlike the acquisition of other complex morphological forms (see Chapter III and V). Where does this rule come from? How does it work? How irregular can the list be before children dismiss a rule-based path? I do not want to spoil all of the details here, but let me look back at cardinal acquisition and bring up one final recurring finding. Children must have some substantial understanding of cardinals before they can begin to understand ordinals. This makes sense both linguistically and conceptually speaking: ordinals quite literally build on cardinals, and we need a solid foundation upon which to build — perhaps this explains the deviant pattern. Chapter III (repeated in IV) fleshes out the stages in ordinal acquisition and makes the learning procedure I put forward explicit, but I saved the ‘other questions’ for Chapter V.
4. Research Questions
In summary, this dissertation investigates how children acquire ordinal numerals, by addressing the questions (i)–(iv) below.

(i) Does the pattern and timing of ordinal acquisition differ from that of cardinals, and if so, can these differences be related to linguistic factors? (Chapter II)
(ii) How does the development of ordinal production compare to the development of ordinal comprehension, and do children generalize an ordinal formation rule? (Chapter III)
(iii) Are strictly rule-based ordinals always comprehended before more frequently and normally used irregular forms, even if those rule-based forms are ungrammatical, infrequent or limited to certain contexts? (Chapters III and IV)
(iv) Does ordinal acquisition follow a rule-based pattern in English, and how does this process compare to Dutch? (Chapter IV)

The last section of this first book on ordinals concludes with some discussion and answers to these questions in Chapter V.
Chapter II

Comparing cardinal and ordinal acquisition

1. Introduction

A recurring finding in developmental psychology is that children slowly discover the exact meanings of cardinals one through four in a tiered fashion before becoming fully competent counters (i.a. Le Corre & Carey 2007). Linguistic knowledge is argued to play an important role in this process, both in the initial stages and in helping children overcome the limitations of innate, nonverbal, number systems (e.g., Carey 2009, Izard et al. 2008). Something similar applies to ordinal numerals as well: children need to learn which counting principles to apply and they need linguistic cues and forms to do so, which is not necessarily a straightforward process. However, the role of linguistic knowledge is potentially different in the ordinal situation, as the morphological complexity of ordinals may help (or hinder) children to grasp ordinal meaning, whereas the linguistic form of cardinals offers nothing to help children acquire cardinal meaning.

This raises the question whether the pattern and timing of ordinal acquisition also differs from that of cardinals, and if so, whether these differences can be related to linguistic factors. The goal of this study is to answer these questions by comparing Dutch children’s understanding of cardinals and ordinals: not only has ordinal acquisition received little attention in general, but such a systematic comparison to cardinals is absent from the literature altogether (Colomé & Noël 2012; Fischer & Beckey 1990; Trabandt et al. 2015; Miller et al. 2000).

On the basis of a Give X task administered to 77 Dutch children, we show that cardinal and ordinal comprehension patterns develop differently, both with respect to their pattern as their timing. Whereas cardinals are acquired lexically and in a stepwise fashion, our data suggest that ordinals are acquired via rules: though children do find lower ordinals

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generally easier than higher ones, it seems the morphosyntactically irregular *derde* ‘third’ is the hardest of all. At the very least, this suggests that a transparent relationship with the corresponding cardinal is beneficial, but we take an even stronger stance, arguing it is indicative of rule-based learning. We also show that earlier stages of ordinal acquisition are influenced by the singular-plural distinction and superlative morphology.

2. Developing numerical and linguistic knowledge

Various studies have shown that humans and animals alike are equipped with two innate systems that can be used for representing numerical concepts: a so-called Approximate Number System (ANS) for imprecise representations of large numerical magnitudes and an Object Tracking System (OTS) that allows for exact representations of up to three or four individual objects (e.g., overviews in Feigenson, Dehaene & Spelke 2004; Spelke & Kinzler 2007). However, these systems do not provide us with the means to reason about exact quantities beyond that upper boundary. It seems children employ another uniquely human capacity to overcome the boundaries of the initial state of these number systems and develop adult-like numerical concepts: language (Hurford 1987; Carey 2009; Spelke 2011).

This begs the question: which aspects of language (e.g., the count list, quantifiers, grammatical number) are relevant here and how do they help to bring the ANS and OTS together? This question has been a recurring topic in the literature for decades (see e.g., Carey 2009; Le Corre & Carey 2007 for overview and discussion), and is not something that we can address in detail here. However, assuming that language does play some important part, we may wonder whether we expect cross-linguistic differences to affect the development of number (in other words: is it the language capacity that drives this development, or specific properties of a given language?) and whether we might see effects of the interplay between language and core knowledge of number beyond the scope of cardinals — in the current study, in the ordinal domain.

2.1. Cardinal acquisition

To address the first question, we need to know what the pattern and timing of cardinal acquisition typically looks like. Various studies have shown that children need time to acquire the exact meanings of cardinals
and master verbal counting (e.g., Condry & Spelke 2008; Huang, Spelke & Snedeker 2010; Le Corre, Van de Walle, Brannon & Carey 2006; Le Corre & Carey 2007; Le Corre, Li, Huang, Jia & Carey 2016; Li, Le Corre, Shui, Jia & Carey 2003; Sarnecka & Gelman 2004; Sarnecka, Kamenskaya, Yamana, Ogura & Yudovina 2007; Wynn 1992). From a so-called ‘knower-level’ perspective, children progress through different stages before becoming fully competent counters. Children start this process by reciting a count list, though they may not do this correctly and do not understand the exact meaning of each number word. They begin to grasp these exact meanings in a slow and stepwise fashion, first distinguishing between one and the other numerals. In this stage, children advance from so-called ‘pre-knowers’ (pre-number knowers, with an inexact understanding of cardinals) to ‘one-knowers’, who know that one means precisely one, and that the other cardinals are more than that. Next they learn the meaning of two: ‘two-knowers’ have exact representations of one and two, but will give a random larger number when asked to give other numerosities. Likewise, ‘three-knowers’ can answer correctly when asked for up to three items, and ‘four-knowers’ (though not found in all studies) for up to four. Together, children in these stages are referred to as ‘subset-knowers’, since they know a subset of the numerals in their count list.

After four, however, children are able to infer the meanings of all the other numerals in their count list and become cardinal principle (CP) knowers. These children answer a question of how many by replying with the last named cardinal after counting, indicating knowledge of at least three counting principles: the one-to-one correspondence principle (every cardinal belongs to one counted item, object, sound et cetera), the stable order principle (the count list has a strict order), and the cardinality principle (the numerosity of the set is equal to the last number counted). Gelman & Gallistel (1978) also name two other principles that are not necessarily crucial here: the order-irrelevance principle (the order in which the items themselves are counted does not matter) and the abstraction principle (that counting can be applied to all sorts of modalities and situations).

Though the evidence for this slow and sequential process of cardinal acquisition is robust, it is also quite clear that the start and duration of each stage vary greatly, both between studies and between individuals. Children generally move through the pattern above somewhere between the ages of two and four, with the lower subset-level stages typically being the longer ones (potentially lasting six to nine months), and the higher
ones the shortest. Most American English-speaking children become CP-knowers between the ages of 3;06 and 4;0, though these same studies also show that children well into their fours can still be in the lower subset-knower stages (e.g., Huang et al. 2010, Le Corre & Carey 2007).

In order to become such fully competent counters, i.e., in order to map the meanings of early numerals to exact cardinalities, children may rely on different linguistic cues, such as knowledge of singular-plural marking (as argued in Carey 2004, 2009, but see Clark & Nikitina 2009, Barner, Chow & Yang 2009, Barner, Lui & Zapf 2011 for a different perspective), given their ability to distinguish one versus more-than-one. Quantifiers, which are semantically close to cardinals (both denoting a quantificational property of a set), have been argued to play a role as well (Barner & Bachrach 2010; Barner, Chow & Yang 2009; Barner, Libenson et al. 2009; Bloom & Wynn 1997). Quantifiers and cardinals in English also show similar syntactic behavior. They can both modify count nouns (three boxes, some boxes) and can occur in partitive constructions (three of the boxes, some/all of the boxes, *big of the boxes), but cannot appear between an adjective and the noun it modifies (*the big three boxes, *the big some boxes, but the big heavy boxes is fine). A third cue may come from count (versus mass) syntax, given that individuation is relevant for counting (e.g., Barner & Snedeker 2005, 2006; Bloom & Wynn 1997; Li, Barner & Huang 2008). Granted, these properties and examples are not exhaustive and somewhat simplify the situation, but they nonetheless illustrate the types of information children may use in bootstrapping knowledge from one category to another (see also Syrett, Musolino & Gelman 2012).

Because languages vary with respect to properties like those listed above, the question now arises to what extent learners of different languages show the same patterns and timing in cardinal acquisition. Though the vast majority of research has focused on middle-class American children, some cross-linguistic work has also been done. The studied languages vary greatly (Japanese in Barner, Libenson et al. 2009 and Sarnecka et al. 2007; Russian in Sarnecka et al. 2007; Slovenian in Almoammer, Sullivan, Donlan, Marušič, Žaucer, O’Donnell & Barner 2013; Saudi-Arabic in Almoammer et al. 2013, Mandarin in Almoammer et al. 2013, Le Corre et al. 2016, and Tsimane’ in Piantadosi 2014) and are spoken in geographically and culturally different places, but what they have in common is that they all differ crucially with respect to the suggested linguistic cues above. For example, they do not (obligatorily)
distinguish singular and plural (Japanese), or they also mark dual (Slovenian, Saudi-Arabic) or inflect numerals for case (Russian). Yet despite these cross-linguistic differences, all of these studies succeeded in classifying children in terms of knower-levels, and all offer support for the idea that this pattern of cardinal acquisition is universal. The timing, however, varies, both within as well as across samples. Explanations for this variation have been argued to lie in differences in morphosyntax (i.e., precisely the reason why these languages were studied) and the quality of exposure. In other words, how and where a language marks number affects the speed of cardinal acquisition: having rich numerical syntax helps, as does being able to combine numerals and nouns directly (as opposed to using a classifier), but frequency on its own does not seem to matter if the context in which numerals are used is less informative. This context may be interpreted as syntactic, but it may also very well be linked to explicit training (e.g., Almoammer et al. 2013). This potential effect of exposure makes it difficult to disentangle linguistic effects from cultural ones, precisely because these languages are both linguistically and culturally diverse. Therefore, focusing on a language more similar to English (minimizing the linguistic distance) with respect to the cardinal domain would provide us with a cleaner basis for investigating potential influential factors within the ordinal domain. We use Dutch, for which (to our knowledge) cardinal acquisition has yet to be studied, for this purpose. We return to Dutch in section 2.3, and turn now to what is known about ordinal development.

2.2. Ordinal acquisition
Ordinal numerals are semantically similar to cardinals in the sense that counting principles and exact number are key. As in the cardinal situation, children must learn which counting principles to apply to determine ordinality and they may use linguistic cues and forms to help them do so. Many of the counting principles that apply to cardinals (the stable order principle, the one-to-one correspondence principle, and the abstraction principle; see above and e.g., Gelman & Gallistel 1978) also apply to ordinals. The cardinality principle and the order irrelevance principle are exchanged for two others: the ordinality principle (that the ordinal refers to a specific item counted in the set rather than the whole set) is crucial in determining ordinality, and the order relevance principle (that the order in which elements are counted influences that element’s ranking) is
needed to do so correctly. Children also need a certain linguistic form to express the position of a referent relative to a deictic center. While they could also use cardinals to assess and express such a rank (i.e., car one, car two, et cetera; see Wiese 2007), adult speech generally seems to favor synthetic ordinal numerals, which may be derived transparently from the corresponding cardinal (as in four-th) but do not have to be, especially in lower ordinals (first, second, third; see Hurford 1987; Veselinova 1998).

Despite this conceptual and linguistic relationship, and despite the hypothesis that language is key in numerical development, surprisingly little is known about how cardinal and ordinal acquisition compare. Systematic empirical work on the acquisition of ordinals is nonexistent, and the small handful of studies that have been carried out in the past few decades all focus on different languages (see Fischer & Beckey 1990 for English, Miller, Major, Shu & Zhang 2000 for English and Chinese, Colomé & Noël 2012 for French, Trabandt, Thiel, Sanfelici & Schulz 2015 for German), different age groups (between 3 and 10 years), focus on limited numerals, and employ different types of methods. This makes it difficult to draw any strong, meaningful conclusions from their results. For example, none of these studies test all of the first four ordinals (making it impossible to distill a knower-level type pattern), none of them included more than two trials per numeral condition, and only Colomé & Noël (2012) tested the cardinals and ordinals in a minimally different way (i.e., matched the items and the method), though the lack of trials impeded comparison anyway. However, such shortcomings notwithstanding, it seems these studies might suggest a number of tendencies when put together.

First, perhaps unsurprisingly, it seems that ordinal acquisition begins later than cardinal acquisition. Not only can children count further using cardinals than ordinals (Miller et al. 2000), they also perform better on cardinal trials than on ordinal trials (Fischer & Beckey 1990; Colomé & Noël 2012). This cardinal advantage can also be seen by comparing cardinal and ordinal performance at set ages.1 Around the age at which

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1 Though not explicitly demonstrated, this observation could also be deduced from other studies that measured knowledge of second and third as a pretest for a different purpose. Matthei (1982) excluded 6 out of 41 children (roughly 15%) between the ages of 3;09 and 6;03 (mean 5;01, median 5;03) for failure to demonstrate knowledge of second and/or third. Hamburger & Crain (1984) excluded 14 out of 59 kids (24%) for this reason (average age failers: 4;11, range 4;05–5;09). The vast majority of the children in these studies should have been in the CP-knower stage.
many children are CP-knowers, four-year-olds still show difficulty comprehending ordinals: only 35% of American children can identify the fifth (Fischer & Beckey 1990), just 41% of their French-speaking peers can find the troisième ‘third’ or quatrième ‘fourth’ (Colomé & Noël 2012), and a little more than half of the German four-year-olds Trabandt et al. (2015) tested could find the zweite ‘second’ or dritte ‘third’. This puts ordinal comprehension well below the cardinal level at these ages. Though performance improves with age in the French and German groups, with many children being at ceiling by age five, American six-year-olds still struggle with ordinals around 34% of the time (Miller et al. 2000). However, note this final percentage is a mean score: in fact, 17 out of 31 American 6-year-olds obtained a perfect score, meaning that a little less than half of the children must have performed well below chance. This suggests that ordinals are acquired simultaneously, rather than one at a time, and thus that we are looking at rule-based, rather than lexical, learning.

However, perhaps ordinal acquisition does follow some progression, as there is also some evidence that lower ordinals are easier than higher ones. Fisher & Beckey (1990) report that third is easier than fifth (31% and 25% correct, respectively), Colomé & Noël (2012) show that sixième ‘sixth’ and septième ‘seventh’ are harder than troisième ‘third’ and quatrième ‘fourth’ in children aged three to five, and Trabandt et al. (2015) report zweite ‘second’ being easier than dritte ‘third’ for some four-year-olds (though this difference did not reach significance). None of the studies are able to report tiered patterns as found in cardinal acquisition (mostly due to the small selection of ordinals tested), but it appears that the place in the ordinal count list might influence a child’s performance on a given ordinal in at least some way.

Another tentative conclusion is that the ordinal acquisition pattern is language-specific. Of course direct comparisons are not possible on the basis of the existing results, but the previous studies at least hint at Chinese children being the quickest: they are at ceiling by age six, even on higher ordinals up to seventh (Miller et al. 2000). Children acquiring English appear to be the slowest, lagging behind their (French-speaking) Belgian and German peers at age four and five. While these timing differences could have to do with unrelated (e.g., cultural) factors, it seems plausible that morphology is the key factor; i.e., that regular ordinals are easier to acquire than irregular ones. Chinese ordinals, formed by adding prefix di– to a cardinal base, are nearly all regular. So are French ordinals.
(cardinal plus –ième), except for the suppletive première ‘first’. German erste ‘first’ is also suppletive, and root allomorphy occurs in dritte ‘third’ (not *dreite; regular ordinals are formed by adding suffix –te to a cardinal). English has the least transparent ordinal system in this group, since only fourth follows regular ordinal formation among the lower ordinals. French production data in Colomé and Noël (2012) also suggest that transparency is preferred in a different way: the authors report that most of the participants gave an analytic construction containing a cardinal numeral (such as the equivalent of car three) in an ordinal production task, rather than an ordinal numeral. In other words, perhaps (in)transparency in the ordinal system affects acquisition, though whether this applies only to the linguistic forms or also influences understanding of the underlying concepts remains an open question (as also noted by Miller et al. 2000 and Colomé & Noël 2012). Equally unclear is whether the syntax of ordinals also plays a role (as does a rich numerical syntax in cardinal acquisition).

When taken together, the studies above suggest that, besides age, three factors play some role in ordinal development: cardinal knowledge, the place of an ordinal in the count list, and the regularity of that ordinal. However, due to the methodological shortcomings mentioned above, none of this can be said with certainty, and the exact contributions of each factor cannot be determined at all. In order to tease these potential influential factors in ordinal acquisition apart, we need to focus on this interplay within one language, rather than cross-linguistically. Hence, we need to study a language that has an ordinal system that is in between a highly regular and a highly irregular one. As mentioned, we use Standard Dutch for this purpose here.

2.3. Dutch as a case study
Though most cardinal acquisition studies focus on languages that differ from English in crucial ways (e.g., the use of duals or a lack of plural marking), our goal is to minimize these differences. This should also minimize differences in cardinal acquisition, giving us a type of ‘baseline’ for studying ordinals. Given existing research and our present goals, we choose Dutch for this purpose.

For one, the cardinal system is similar to English but the knower-level acquisition pattern has (to our knowledge) not yet been verified for Dutch. Dutch is similar to English in other respects that have been suggested to be linked to the development of numerical concepts, such as
number marking, the mass/count distinction and quantifiers (see references in section 2.1). Dutch distinguishes between singular (null suffix) and plural (typically suffix –s or –en) on count nouns. As in English, mass and object mass nouns receive no special suffix; flexible mass nouns receive a count interpretation when pluralized. Both quantifiers and numerals modify count nouns (sommige/geen/veel/drie dozen ‘some/all/many/three boxes’) and can occur in partitive constructions (sommige/geen/veel/drie van de dozen ‘some/none/many/three of the boxes’). Note that there are also differences between Dutch and English in quantification, such as universal quantifiers iedere and elke versus each and every (see Van Koert, Koeneman, Weerman & Hulk 2015, Van Koert, Hulk, Koeneman & Weerman 2015 for how this plays out in acquisition), and measure phrase constructions (e.g., a twenty-pound pumpkin versus een pompoen van twintig pond, lit: ‘a pumpkin of twenty pound’). However, the former have not been linked to cardinal acquisition, and the latter are acquired after cardinals (Syrett 2013). For another, the Dutch ordinal system is more regular than English, yet less regular than ordinal systems of other languages discussed in ordinal acquisition above (i.e., French and Chinese, and to a lesser extent even German). These two properties can be observed in Table 1, which shows the Standard Dutch cardinal and ordinal list through twintig ‘twenty’.

Table 1: Cardinal and ordinal formation in Standard Dutch

<table>
<thead>
<tr>
<th>#</th>
<th>Cardinal</th>
<th>Ordinal</th>
<th>#</th>
<th>Cardinal</th>
<th>Ordinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>één</td>
<td>eer–ste</td>
<td>11</td>
<td>elf</td>
<td>elf–de</td>
</tr>
<tr>
<td>2</td>
<td>twee</td>
<td>twee–de</td>
<td>12</td>
<td>twaalf</td>
<td>twaalf–de</td>
</tr>
<tr>
<td>3</td>
<td>drie</td>
<td>der–de</td>
<td>13</td>
<td>der–tien</td>
<td>der–tien–de</td>
</tr>
<tr>
<td>4</td>
<td>vier</td>
<td>vier–de</td>
<td>14</td>
<td>veer–tien</td>
<td>veer–tien–de</td>
</tr>
<tr>
<td>5</td>
<td>vijf</td>
<td>vijf–de</td>
<td>15</td>
<td>vijf–tien</td>
<td>vijf–tien–de</td>
</tr>
<tr>
<td>6</td>
<td>zes</td>
<td>zes–de</td>
<td>16</td>
<td>zes–tien</td>
<td>zes–tien–de</td>
</tr>
<tr>
<td>7</td>
<td>zeven</td>
<td>zeven–de</td>
<td>17</td>
<td>zeven–tien</td>
<td>zeven–tien–de</td>
</tr>
<tr>
<td>8</td>
<td>acht</td>
<td>acht–ste</td>
<td>18</td>
<td>acht–tien</td>
<td>acht–tien–de</td>
</tr>
<tr>
<td>9</td>
<td>negen</td>
<td>negen–de</td>
<td>19</td>
<td>negen–tien</td>
<td>negen–tien–de</td>
</tr>
<tr>
<td>10</td>
<td>tien</td>
<td>tien–de</td>
<td>20</td>
<td>twin–tig</td>
<td>twin–tig–ste</td>
</tr>
</tbody>
</table>

Van Witteloostuijn & Schaeffer (2018) show that it is also unclear to what extent the acquisition of the mass/count distinction in Dutch and English is completely comparable in terms of pattern and timing, though in both languages count nouns occur first. which is attributed to count nouns having more overt syntactic cues (plural marking, indefinite determiners, and, interestingly, numerals) than mass nouns.
Similar to English, the first twelve cardinals are monomorphemic and the cardinals from *dertien* ‘thirteen’ to *negentien* ‘nineteen’ are formed by compounding with –tien ‘ten’. *Twen–tig* ‘twen–ty’ follows from root allomorphy plus the suffix –tig. Ordinals are derived by adding either a suffix –de or –ste to a cardinal. Ordinals for up to and including *twaalf* ‘twelve’ receive –de (as for the other ordinals through *negentien* ‘nineteen’), with the exception of ordinals for *één* ‘one’, *drie* ‘three’, and *acht* ‘eight’. All higher ordinals end in –ste (e.g., *twintigste* ‘twentieth’), as do indefinite ordinals (e.g., *zoveelste* ‘umpteenth’, lit: ‘so-many-th’).

The irregularities found in *eerste* ‘first’, *derde* ‘third’, and *achtste* ‘eighth’ differ crucially from each other. We take *achtste* to be regular, except that it takes the suffix generally used for higher ordinals, while *derde* is the result of root allomorphy in combination with the regular ordinal suffix –de. Though one might think *eerste* could be a product of both of these explanations (i.e., root allomorphy plus –ste), it seems more plausible to consider it a case of suppletion, in which a superlative is used. In other words, –ste is not an ordinal suffix here at all, but the (homophonous) –ste suffix that is also used to create superlative adjectives, such as *lang–ste* ‘tall–est’. Not only do Hurford (1987) and Veselinova (1998) note that ordinals for *first* in many languages come from a temporal or spatial superlative adjective, Barbiers (2007) argues that *eerste* ‘first’ is a superlative for (synchronic) syntactic reasons. Unlike ordinals, Dutch *eerste* can modify plural nouns and can lose its final schwa (*eerst* ‘first’, but *achtst* ‘eighth’), and can also be intensified by *aller*– ‘very’ (*allereerste* ‘very first’, but *allerachtste* ‘very eighth’). These are all properties that *eerste*, but not other ordinals, shares with superlatives. Moreover, *eerste* arguably has a corresponding positive and comparative form: *eer, eerder* ‘fore, former’, at least diachronically.

This contrast between *eerste* ‘first’ and other ordinals is important to point out. For one, this has implications for the effects of morphology that might play a role in acquisition: if *eerste* is acquired as superlative rather than an irregular ordinal, children may bypass potential negative effects of irregular ordinal morphology, and potentially benefit from existing superlative knowledge.\(^3\) For another, ordinals cannot modify

\(^3\) See Syrett (2016) for an overview of the acquisition of comparatives and degree constructions. Though there are differences between comprehension and production, and between different kinds of comparative constructions, it is clear that comparative and superlative acquisition begins around the age of three (i.e., before cardinals).
plural nouns (and thus only appear with singular nouns), whereas eerste ‘first’ can appear with both singular and plural nouns. As a result, it may be possible for children to deduce that ordinals refer to individuals, rather than an entire set (as is the case with cardinals and sometimes eerste ‘first’). Put differently, the syntactic context of eerste, like laatste ‘last’, does not help to acquire ordinals as a class because eerste is not part of that class.

Another property that might influence acquisition and sets eerste ‘first’ apart from other ordinals, is frequency. Table 2 below presents frequency data from the SUBTLEX (Keuleers, Brysbaert & New 2000) and Corpus Gesproken Nederlands ‘Spoken Dutch Corpus’ (Oostdijk 2000) corpora.

Table 2: Frequencies of the first twenty ordinals in Dutch. The Abs-columns are absolute frequencies per 1 million words per corpus; the Rel-columns represent the relative frequency within all tallied ordinals through twintigste ‘twentieth’.

<table>
<thead>
<tr>
<th>Ordinal</th>
<th>SUBTLEX</th>
<th>CGN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abs</td>
<td>Rel</td>
</tr>
<tr>
<td>1</td>
<td>471.61</td>
<td>60.50%</td>
</tr>
<tr>
<td>2</td>
<td>129.82</td>
<td>16.65%</td>
</tr>
<tr>
<td>3</td>
<td>76.49</td>
<td>9.81%</td>
</tr>
<tr>
<td>4</td>
<td>25.61</td>
<td>3.29%</td>
</tr>
<tr>
<td>5</td>
<td>17.88</td>
<td>2.29%</td>
</tr>
<tr>
<td>6</td>
<td>11.02</td>
<td>1.41%</td>
</tr>
<tr>
<td>7</td>
<td>9.01</td>
<td>1.16%</td>
</tr>
<tr>
<td>8</td>
<td>5.97</td>
<td>0.77%</td>
</tr>
<tr>
<td>9</td>
<td>5.21</td>
<td>0.67%</td>
</tr>
<tr>
<td>10</td>
<td>7.27</td>
<td>0.93%</td>
</tr>
<tr>
<td>11</td>
<td>2.42</td>
<td>0.31%</td>
</tr>
<tr>
<td>12</td>
<td>3.84</td>
<td>0.49%</td>
</tr>
<tr>
<td>13</td>
<td>2.63</td>
<td>0.34%</td>
</tr>
<tr>
<td>14</td>
<td>2.06</td>
<td>0.26%</td>
</tr>
<tr>
<td>15</td>
<td>1.72</td>
<td>0.22%</td>
</tr>
<tr>
<td>16</td>
<td>2.38</td>
<td>0.31%</td>
</tr>
<tr>
<td>17</td>
<td>0.75</td>
<td>0.10%</td>
</tr>
<tr>
<td>18</td>
<td>1.23</td>
<td>0.16%</td>
</tr>
<tr>
<td>19</td>
<td>0.91</td>
<td>0.12%</td>
</tr>
<tr>
<td>20</td>
<td>1.65</td>
<td>0.21%</td>
</tr>
</tbody>
</table>

The first database, SUBTLEX, consists of 44 million words from film and television subtitles. The second database (CGN) contains roughly 9 million
words in 1000 hours of speech files from the Netherlands and Flanders. The tallied frequencies in the A-columns are frequencies per million words for each corpus. Only fully spelled ordinals were counted (i.e., tweede was counted but not the abbreviated form 2e). For eerste, both the forms with and without the -e were included, irrespective of how they were annotated syntactically. Compounds and cases with e.g., aller– intensification were excluded. Still, eerste is clearly more frequent than all other ordinals in Table 2 combined, as it comprises more than half the attested cases in both corpora (B-columns). The crucial observation here is that while frequency may play a role in the acquisition of the lowest ordinals, it quickly becomes difficult to maintain effects of (token) frequency past vijfde ‘fifth’, as the frequencies become marginally small and similar (all under 2.5% of the ordinals tallied).

2.4. Research questions
The literature on cardinal acquisition, ordinal acquisition and Dutch ordinal formation brings us to three topics of inquiry. The first question is whether cardinal acquisition in Dutch follows the same pattern and timing as described for other languages, especially English. We expect that it does: previous studies strongly suggest that the knower-level pattern is universal. Moreover, since Dutch is similar to English in many relevant respects, we also hope for a relatively clean comparison (linguistically speaking) to English. However, the studies discussed above show that the timing of cardinal acquisition varies considerably both within and between samples, which makes it difficult to predict ages of acquisition for any knower-level in any exact terms.

The second and primary goal of this study is to investigate the patterns and timing in ordinal acquisition, and what factors play a role in this process. Specifically, we ask whether age, cardinal knowledge, (ir)regular morphology, and the place in the ordinal count list predict children’s comprehension of given ordinals, and how these factors interact. First, we expect older children to perform better than younger children and higher ordinals to be more difficult than lower ordinals. Second, the morphological complexity of ordinals suggests that children should acquire a cardinal before its corresponding ordinal. There are two ways in which ordinal morphology might affect acquisition, which we would like to refer to as the weak hypothesis and the strong hypothesis.
Under the weak hypothesis, ordinals are acquired lexically, much in the same way cardinals are: one by one in a truly tiered fashion. If ordinals are acquired lexically, higher ordinals are expected to be more difficult for the same reasons higher cardinals are (and because higher ordinals are less frequent than lower ones), the acquisition of ordinals would be progressive, and not necessarily reliant on their derivation from cardinals. Irregular *derde* ‘third’ could be more difficult due to the lack of transparency, since the form provides no clues to its meaning. Put differently, a transparent relationship between cardinals and ordinals can be helpful in determining their meaning, but neither such transparency nor a full and exact understanding of cardinality is crucial. Perhaps this scenario is more easily imaginable for the English ordinal system, where the first ordinals are so irregular that children might learn ordinals one after another (but independently of their corresponding cardinals) rather than ‘wait’ for a rule.

Under the strong hypothesis, children use an ordinal formation rule to acquire all (regular) ordinals simultaneously; they use the form to acquire ordinal meaning. This would mean they acquire ordinals as a class, and ordinals would necessarily have to be acquired as or after children become CP-knowers: without an exact understanding of the cardinal root, it is impossible to determine the contribution of the suffix to that root to reach ordinal meaning. Exceptions to this rule (like *derde* ‘third’) are then acquired later than regular forms like *vierde* ‘fourth’, because children cannot decompose the ordinal into recognizable parts. Higher ordinals may also be more difficult, but for non-linguistic reasons (though the slightly deviant suffix for *achtste* ‘eighth’ may also cause extra difficulty).

One question is whether subset-knowers can begin to acquire ordinals via a rule-based strategy. If they can, the prediction is that children would be able to apply the rule to cardinals that they know, and then learn the remaining ordinals and cardinals in tandem. In such a situation, a tiered pattern in acquisition (as in the weak scenario) would be visible. However, the question is how children could apply a productive rule to an unproductive and limited cardinal system. Subset-knowers (perhaps with the exception of four-knowers, who are on the cusp of cardinal acquisition) have such an incomplete representation of cardinals and cardinality that we find it difficult to imagine how the ordinal formation rule would work in that case: without the proper counting principles, without the knowledge that cardinals refer to discrete entities,
without the proper semantics of the cardinal root — how are they to conceive of a productive and meaningful rule for the contribution of the ordinal suffix and thus ordinals? In other words, if the strong hypothesis predicts a tiered pattern at all, it would consist of three or four steps: first, children know no ordinals at all, then all regular ordinals (derived from cardinals that children already know), then irregular ordinals (lexically), with an optional tier to distinguish low (up to fourth) and high ordinals if the rule is acquired before children can put it into practice reliably in longer count lists. Note that while the weak (or lexical) hypothesis suggests that the acquisition of ordinals is likely better predicted by age than by cardinal knowledge specifically, the strong hypothesis suggests that ordinal acquisition is necessarily determined by cardinal knowledge: regardless of age, ordinals cannot be acquired unless the relevant cardinal knowledge is in place.

Our third question is geared mostly towards children in earlier stages of ordinal development: are there other linguistic factors (such as the singular-plural distinction, or regular superlative morphology) that might help start ordinal acquisition? If number marking plays a role, we would expect children to take just one item when asked for any ordinal, regardless of whether they know the exact meaning of that ordinal, and regardless of their knower-level. If knowledge of superlatives matters (or if frequency helps), we expect eerste ‘first’ to be acquired before ordinals.

3. Method

Children’s comprehension of cardinals has been tested in various studies using varieties of the ‘Give-a-Number’ paradigm, a selection task also known as a ‘Give me’ or ‘Give X’ task (e.g., most notably Wynn 1992, but also Almoeamer et al. 2013, Colomé & Noël 2012, Condry & Spelke 2008, Huang et al. 2010, Le Corre et al. 2006, Trabandt et al. 2015, Li et al. 2003, Sarnecka & Gelman 2004, Sarnecka et al. 2007, among others). The present study adapted this paradigm in order to directly compare cardinal and ordinal acquisition.

3.1. Participants
In total, 77 children (40 boys, 37 girls) participated in this experiment. We divided children in three age groups during testing: three-year-olds ($N = 31$, mean age = 3;06, $SD = 3.5$ months, range=2;11–3;11), four-year-olds ($N = 26$, mean age = 4;06, $SD =3.1$ months, range = 4;0–4;11) and older
kindergartners ($N = 21$, mean age $= 5;06$, $SD = 5.13$ months, age range $= 5;0–6;04$). All participants were typically-developing monolingual Dutch children. An additional 8 children were excluded from analysis because they did not complete both sessions of the task.

3.2. Materials and procedure
All children were tested on the cardinals one through four, and eight, as well as on their corresponding ordinals (first through fourth, eighth). Because each numeral appeared three times, the initial task consisted of 30 critical trials. We later incorporated items for nine to exclude the possibility that achtste ‘eighth’ was misheard as achterste ‘backmost’, and to check for general consistency within the higher ordinal trials. This version of the task contained 36 critical trials and was completed by 29 participants. The filler conditions were the degrees of comparison of groot ‘big’, klein ‘small’, lang ‘long’, dik ‘fat’, and veel ‘many’, plus the indefinite ordinals middelste ‘middle–est’ and laatste ‘last’, which together represented 41 items in the total task. We divided the task into two sessions: one for cardinals, and one for ordinals. In addition, children were asked to count to twenty at the end of each session. We presented items in one of eight pseudo-random orders within each session and we counterbalanced which session was administered first between participants within each age group. We administered the second session within a week of the first. Sessions lasted approximately fifteen to twenty minutes each. See the Appendix for a full list of stimuli and a description of the test orders.

The materials consisted of a stuffed animal (Jaap the monkey), two paper suitcases (printed on heavyweight craft paper, then cut and pasted together), and plastic containers which held the actual items: laminated cards (4.5 x 4.5 cm) with images of everyday objects and animals. For ordinal items, the pictures used had clear fronts or faces in order to emphasize the direction of the line. The number of items in line depended on the cardinal or ordinal: the lowest numerals (one, two, first and second) all had four cards in line; numerals three, four, third and fourth had six cards, and the higher numeral items consisted of ten cards. The reason the

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4 In other words, we did not use the titration method described in e.g., Wynn (1992), Barner et al. (2009) or Le Corre et al. (2006) but tested all children on all numerals mentioned. Though the titration method prevents unnecessary testing on higher numerals, it might also inherently reflect a tiered acquisition pattern.
length of the line varied was a practical one: putting more cards on the table adds to the total testing time and increases the materials needed.

Children were tested individually at their school or daycare center, either in a separate room or in a quiet corner of the classroom. They were seated to the left of the experimenter and to the right of the monkey and his suitcases (see Figure 1), and introduced to the materials and the task by a short story, as translated in (1).

Figure 1: Experimental setup for de tweede eend ‘the second duck’. M is the monkey, S the score person, C the child, E the experimenter. Image not to scale.

(1) Introductory story

This is Jaap. Jaap is a very friendly monkey. And pretty soon he’s going on a trip. He doesn’t know where he’s going (it’s a surprise) but he’s super excited about it. He told all of his things that he’s leaving and guess what? Now all of his things want to come along! They’re even getting in line to jump into his suitcase. [Experimenter demonstrates line with a gesture.] But Jaap has a little problem, because look: he has a whole lot of things, and only two suitcases: a yellow one, and a white one. [Experimenter points to each suitcase.] So not everything is going to fit, huh? So Jaap needs a little help, and I think the two of us would be really good at helping him out. What do you think? Do you want to help the monkey?

After the story, children were allowed to pick which of the two suitcases they wanted to begin with. Two practice items then helped to acquaint them with the task and the materials at the beginning of each session. For each item (both during and after the practice phase), cards were placed one by one in front of the child in a straight line, starting near the suitcase and working from left to right. This way, a child could access an ordinal interpretation both temporally (the \( n^{th} \) placed on the table) and spatially...
(the $n^{th}$ in line). The experimenter pointed out the beginning of the line for both practice items, in which children had to find a certain object *voor aan* ‘at the front’ and *ach ter aan* ‘at the back’ of the line. Most children were able to do so. Those who failed on the practice items were asked to show the experimenter where the line began and/or in which direction the things were going to familiarize them with the general concept of the line. No children were excluded for failure to understand or physically perform the task.

For all further items, children were asked to pack a certain item or collection of items (e.g., *three t-shirts, the second rubber ducky, the last truck, et cetera*) in the suitcase. Literal examples of how items and fillers were offered to the children are given in (2) through (5) for ordinals, cardinals, comparatives and superlatives, respectively.5

(2) De tweede eend mag mee. Kun je de tweede eend vinden en in de koffer doen? 'The second duck gets to come. Can you find the second duck and pack it in the suitcase?'

(3) Er mogen acht stiften mee. Kun je acht stiften tellen en inpakken voor Jaap? 'Eight markers get to come. Can you (count and) pack eight markers for Jaap?'

5 Note that for comparatives, the experimenter pointed to an object on the table to make the comparison explicit. Only the comparative was offered overtly and not a full phrasal comparative (i.e., only *a cat that's fatter* rather than *a cat that is fatter than this cat*). An anonymous reviewer wondered about the acceptability of this type of comparative in Dutch. The comparative we used, such as in example (4), is perfectly acceptable in Dutch, although using the adjective attributively (e.g., *een dikkere poes* ‘a fatter cat’) would have also been grammatical.
(4) Deze poes gaat niet mee. Kun je een poes vinden die
dikker is?
‘This cat isn’t coming. Can you find a cat that’s fatter?’

(5) De kleinste tv mag mee. Kun je de kleinste tv vinden
en inpakken?
‘The smallest tv can come. Can you find the smallest tv and pack it?’

Formulaic variations (e.g., *Jaap zegt dat* ‘the monkey says that’) occurred to keep the setting natural, but typical stimuli offered children the numeral (or filler) as part of a full subject DP; ordinals were often repeated with a definite article (e.g., *de tweede*, ‘the second’), cardinals with a noun (e.g., *acht stiften*, ‘eight markers’). Some children (typically the older ones) were quick to react and/or repeated (part of) the stimulus, in which case repetitions were often left out. The experimenter encouraged children to count aloud but did not always do so when asking for a given item. Follow-up questions (e.g., ‘Can you check/count and make sure?’ or ‘Can you show me that’s eight?’) were asked to allow children to check and correct their responses.

Because we needed a design that emphasized the ordinal and filler contexts naturally, and because our test conditions led to a larger test set than in a standard Give X task, the modifications described above were made in order to make the task more natural, less monotonous and to keep the children engaged throughout. That being said, the monkey puppet played a limited role in the rest of the experiment itself. Jaap was introduced as an ice-breaker in the classroom environment and helped to provide some more context to the story. During the experiment, the experimenter could use the monkey to help keep the child engaged and to

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6 A reviewer worried that how full a suitcase was may have influenced the child’s responses. We did consider this as a potential issue before testing, taking care to use appropriately sized suitcases for the materials (i.e., large enough so that more than the requested items would fit but not so large that a child felt he could have packed everything). We did not test whether children used the suitcase as a strategy, though nothing in their behavior or responses suggested they did.
mediate situations in which the child was confused about an item. (“Really, so you think the third isn’t in line, huh? But the monkey asked for the third car? Where do you think it could be?”) In general, the experimenter behaved as the monkey’s interpreter, asking the child for given items on his behalf. This puts less pressure on the child, since they could always resort to calling the monkey silly or wrong if he ‘asked’ for an ordinal they did not know or thought was ungrammatical, rather than going against (the authority of) the adult experimenter.

3.3. Determining numeral knowledge

We determined a child’s knowledge of cardinals differently than for their knowledge of ordinals. For cardinals, we established a knower-level for each child by applying and comparing two separate measures. First, we took a common approach and considered a child a certain \( n \)-knower when he or she gave \( n \) cards at least two out of three times when asked for that number, and gave \( n \) cards at most once when asked for a different number. These criteria are in line with those reported in e.g., Le Corre & Carey (2007), but because they could be considered crude or ad hoc, we also estimated knower-levels using the tool provided by Negen, Sarnecka & Lee. (2012), which approximates a Bayesian inference of a child’s knower-level (see also Lee & Sarnecka 2010ab).\(^7\) The outcomes of both methods were the same and children were easily categorized in most cases. In the seven cases where the model was inconclusive and/or there was a difference between the two methods, we carefully evaluated the child’s responses (including any notes the score person may have included on the score sheet) to categorize the child. There was never more than one knower-level difference. We chose the more conservative option in five cases.

Since ordinal comprehension is not as well-studied, there are no established criteria or models for determining a child’s knowledge of a

\(^7\) A child’s knower-level can be inferred using the probabilistic generative model developed by Lee and Sarnecka (2010ab) on the basis of a large amount of Give-N data. This model specifies a base rate (put crudely: chance performance) and then modifies this rate following Bayes’s rule. It looks at children’s responses and predicts the probability of children belonging to a certain knower-level given those responses. (I.e., when asked for \( two \) \( ducks \), the probability for giving four is higher for a one-knower than for a three-knower, and the probability for giving two is higher for the three-knower than the one-knower.) This allows us to infer in which knower stage a child most likely is. The tool created by Negen et al. (2012), an Excel spreadsheet, is an easy and accurate way to approximate the inference this model makes.
given ordinal. Though we would have liked to maintain the same criteria for cardinals as for ordinals and compare them as directly as possible, we opted to treat the ordinal acquisition data differently: we depart from the ‘knower’ criteria that we used for the cardinal domain, and apply a more elaborate analysis to the ordinals we tested that helps tease apart effects of age, cardinal knowledge, regularity and the place in the count list. We then discuss *eerste* ‘first’ separately from the rest of the ordinals: since *eerste* ‘first’ is a superlative, not an ordinal (see Barbiers 2007 and discussion in section 2), and hence, a conceptually different entity, discussing those results entirely within the ordinal set is inappropriate.

First, we have to address why the criteria for assessing cardinal knowledge should not be applied in the ordinal situation. The first issue at hand has to do with how errors are treated in determining a child’s knowledge of numerals. Under the cardinal criteria if a child answers incorrectly to a given cardinal (e.g., he gives *four* when asked for *three*) he is penalized on both the requested cardinal and the numeral he provides erroneously (*three* and *four*). This is fine as long as the expectation is that children will properly infer that cardinals are in competition with each other: if a child knows the meaning of *one* and *two*, and he knows that *three* refers to an exact quantity but is unsure of which quantity exactly, he should know that *one* and *two* items are not acceptable answers in that scenario, and he should therefore give a higher number of items in response to that request. The tiered pattern of cardinal acquisition reflects that this inference (or something similar to it) is indeed the case: cardinals are acquired along the list, with errors going in one direction only.

For ordinals, the necessity of such a pattern is far less obvious. Say a child knows every ordinal except *derde* ‘third’, because his ordinal for *third* is *driede* ‘lit: threeth’. Such reasoning would entail that every card a child chooses when asked for *derde* is incorrect or must overlap with an ordinal he does know. A child who then chooses systematically for any given card, would be considered a non-knower of not only *derde* ‘third’, but also that other ordinal. Given that a child has six cards to choose from in this condition, the original knower-determination method would only allow the last two cards as ‘safe’ choices, but this is obviously task-specific and unfair to the child. This is also the case for a child who chooses less systematically on *derde* ‘third’ but happens to get one item wrong elsewhere, selecting the same incorrect card twice.

Because the acquisition pattern of ordinals does not have to be (and, as we argue, is indeed not) tiered in the same way as cardinals, we do not
try to formulate analogous notions of ‘first-knower’, ‘second-knowers’, and so on. Instead, we discuss children’s performance on ordinal trials in terms of (in)correct responses.

4. Results
Before going into the results from the cardinal and ordinal trials, it is worth taking a brief look at the filler items. All children performed well on the positive, comparative and superlative fillers we tested (namely big, small, long, fat and many). Five children (all between 35 and 40 months) scored four out of five of the positive fillers correctly and all other participants answered correctly on all five. Table 3 depicts the mean percentage of correct responses on the comparatives and superlatives per age group.

Table 3: Mean percentage of correct responses to comparatives (comp.) and superlatives (superl.) by age group.

<table>
<thead>
<tr>
<th></th>
<th>Pre-schoolers</th>
<th>4-year-olds</th>
<th>5-&amp;-6-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>97%</td>
<td>87%</td>
<td>100%</td>
</tr>
<tr>
<td>SD</td>
<td>7.02%</td>
<td>10.33%</td>
<td>1.31%</td>
</tr>
</tbody>
</table>

As is immediately obvious, very few mistakes were made on comparatives and superlatives in general. Children also did well on an individual level, as all participants scored at least 11/15 items correctly and most were near ceiling. This high performance rate shows us that children, even those who performed near floor level on all numeral trials, understood the task and were engaged throughout each session.

4.1. Cardinals
Figure 2 is an area plot of the knower-levels by age. Table 4 displays children’s ages at each knower-level, as well as performance on the counting task, for which the highest count of the two sessions was used for each child.

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*There was no significant difference on total test performance between children who took the cardinal sessions first (M correct= 79%, SD = 15%, N = 42) and children who completed the ordinal session first (M = 79%, SD = 13%, N = 35); t = 0.085, p = 0.448. We therefore report the results for both test orders as a whole.*
The data are not only in line with previous studies in that children do in fact seem to acquire the exact meaning of cardinals in stages, but also in that children are typically able to count much further than they can comprehend. Nearly all the children could count to at least ten, which is high enough to have been able to answer all the items in this task correctly. Four-knowers onward generally counted to twenty (which is as far as we asked them to count).

Table 4 also shows that the children in our sample show a wide range of individual differences. Despite this variation, a Spearman’s correlation test reveals that children’s count lists increase with both age in months ($r_s = 0.610$, $p < 0.001$) and knower-level ($r_s = 0.648$, $p < 0.001$); older children also tend to be further along in cardinal comprehension ($r_s = 0.745$, $p < 0.001$). Gender did not seem to play a role. There was no significant difference in how far boys ($M = 14.20$, $SD = 6.726$) and girls ($M = 16.49$, $SD = 4.897$) could count (Mann-Whitney $U = 640.0$, $Z = -1.103$, $p = 0.270$, two-tailed), nor was there evidence for knower-level differences.
between genders (Mann-Whitney $U = 594.0$, $Z = -1.584$, $p = 0.113$, two-tailed).

Though the children in the present study follow the knower-level pattern in acquisition discussed above, Figure 2 suggests Dutch children nonetheless differ slightly from children acquiring other languages. Dutch children seem, on average, slightly slower than other children to become CP-knowers. For example, Almoammer et al. (2013) report that 88% of Slovenian and 80% of American English-speaking children aged 3;0–3;06 knew at least the meaning of *two*, whereas 28% of children in the same age group meet that requirement in our sample. Most American English speakers know the exact meaning of at least *three* by age 3;06 (e.g., Le Corre & Carey 2007, Le Corre et al. 2016, Sarnecka & Carey 2008). Our sample included no children under 3;06 who were three-knowers or better and by age 3;11 only 58% were. Dutch children make up for some lost time, but seem on average slower to become CP-knowers. Huang et al. (2010) report most American English speaking children to be CP-knowers around their fourth birthday, and all of American and Saudi children aged 4;06–5;0 reported in Almoammer et al. (2013) were indeed CP-knowers. Slovenian children are about evenly divided between four-knowers and CP-knowers at this age, whereas the majority of Dutch children are CP-knower from 4;06 on.

Another observation is that there is only one three-knower in our sample, as opposed to the relatively large group of four-knowers. However, the proportions of different subset-knowers vary across studies, as do the ages of the children in these groups. Almoammer et al. (2013) for example report small groups of both the higher subset-knowers in all languages they discuss, while Le Corre & Carey (2007) have more three-knowers than four-knowers. In the present study, there is a large gap between the mean age of the two-knowers and four-knowers, and much overlap in ages between all knower-groups. We return to this later.

### 4.2. Ordinals

Though we used different methods to assess children’s knowledge of ordinals than for cardinals, this does not mean that we cannot attempt to compare cardinal patterns to ordinal ones at all. For example, Figure 3
divides children’s performance on ordinals by the same age groups depicted in Figure 2, the area graph for knower-levels.\(^9\)

Unsurprisingly, the proportion of correct responses on ordinal trials is higher in the older age groups than in the younger ones. This is similar to the cardinal case, in the sense that older children are also more likely to provide correct responses on cardinal trials than younger children. Note that high scores on ordinals appear at a later age than on cardinals, with ceiling scores appearing after the age at which children become CP-knowers. This delay is more visible in Figure 4, which depicts the proportion of correct responses to ordinal trials per knower-level.

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\(^9\) Note that the ordinals included in this analysis, here and onwards, are *tweede* ‘second’, *derde* ‘third’, *vierde* ‘fourth’ and *achtste* ‘eighth’. As explained above, *eerste* ‘first’ has been left out for a priori conceptual reasons. We also excluded *negende* ‘ninth’. Not all participants were tested on *negende* ‘ninth’, but those who were performed similarly on both *achtste* ‘eighth’ and *negende* ‘ninth’: 23 out of 30 children gave exactly the same number of correct responses for each of these ordinals, 4 children had one more correct on *achtste* ‘eighth’ than *negende* ‘ninth’, three children had one more correct on *negende*. No children showed a greater difference in performance. We therefore take the outcomes for both ordinals to be the same, and thus take *achtste* to be regular, despite the difference in suffix.
Figure 4: Percentage of correct responses to *tweede*, *derde*, *vierde* and *achtste* (*second*, *third*, *fourth* and *eighth*, respectively) by cardinal knower-level.

Figure 4 shows that the proportions of correct responses for children in the lower subset-knower levels hovers around 20%, whereas four-knowers provide correct responses roughly three times as often, on average. CP-knowers do at least as well, with many showing at or near-ceiling performance. However, the figure only displays performance on all ordinals combined; Table 5 shows the percentage of correct responses on each ordinal per knower-level group.

Table 5: Percentage of correct responses per ordinal by knower-level.

<table>
<thead>
<tr>
<th>Knower-level</th>
<th><em>tweede</em> 'second'</th>
<th><em>derde</em> 'third'</th>
<th><em>vierde</em> 'fourth'</th>
<th><em>achtste</em> 'eighth'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-knowers</td>
<td>11%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>1-knowers</td>
<td>33%</td>
<td>19%</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td>2-knowers</td>
<td>25%</td>
<td>11%</td>
<td>8%</td>
<td>0.0%</td>
</tr>
<tr>
<td>3-knowers</td>
<td>33%</td>
<td>33%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>4-knowers</td>
<td>69%</td>
<td>48%</td>
<td>67%</td>
<td>21%</td>
</tr>
<tr>
<td>CP-knowers</td>
<td>95%</td>
<td>80%</td>
<td>91%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Table 5 confirms that children in the pre-to-three-knower range show little knowledge of ordinals; note that chance performance is at 25% correct for *tweede* 'second' (as there were four cards to choose from); 17% on *derde* 'third' and *vierde* 'fourth', and 10% for *achtste* 'eighth'. The table also suggests that while both four-knowers and CP-knowers seem to do equally well on the regular low ordinals, irregular *derde* 'third' and high ordinal *achtste* 'eighth' may be more difficult. This is also reflected anecdotally in the ordinals children produced spontaneously in the course of the task: both *driede* and *achtde* occurred. Of course, age and knower-level are
obviously confounded in the figures and table above: we need to determine what cardinal knowledge adds, if anything, to age. The same holds for the other factors we hypothesized to play a role, namely the place of the ordinal in the count list (i.e., are lower ordinals acquired before high ones?) and the regularity of the ordinal (is irregular derde ‘third’ acquired after regular ordinals?).

In order to address these issues, we used R (R Core Team 2016) and the lme4 package to fit a generalized linear mixed-effects logistic regression model (Bates, Maechler, Bolker & Walker 2015) to the data described above. All fixed continuous factors (age in months, knower-level, place in the ordinal count list) were centered before analysis; the fixed categorical variable (ir)regularity was dummy-coded with explicit contrasts before analysis. The dependent variable was whether a child’s response was correct or incorrect. We included participant as a random intercept with random slopes for ordinal.

First, we wanted to determine the effects of age compared to cardinal knowledge. Because the two factors are correlated, we fit a model in which we included the regularity of the ordinal numeral (i.e., whether the ordinal numeral was irregular, as in the case of derde ‘third’, or regular, as for e.g., achtste ‘eighth’) and place in the ordinal count list (continuous) as well as knower-level (continuous) as fixed factors, and compared that to a model in which knower-level was replaced by age (for which $M = 51.76$ months, $SD = 10.44$ months, range = 35–76 months). Including an interaction between knower-level on the one hand, and ordinal and regularity on the other hand, did not significantly improve the model ($\chi^2 = 5.4552$, $df = 2$, $p = 0.06$) and the second model would not converge with an interaction (Ordinal+Regularity)*Age included, so interactions were left out in both cases. Although age was a significant factor within the second model ($Z = 7.943$, $p < 0.0001$), the AIC and BIC were lower for the first model (AIC: 673.86 vs. 676.79, BIC: 707.67 vs 710.59, respectively). We therefore conclude that, although age and

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10 We thank two anonymous reviewers for their detailed suggestions regarding the statistical analysis.

11 Knower-level was treated as a continuous predictor due to modelling difficulties with knower-level as an ordered factor, given the relatively limited number of children within some knower-levels and the distribution of children across knower-levels. It would be interesting to explore what, if any, added benefit there is per increase in knower-level, especially for the progression from 4- to CP-knower.
knower-level are correlated, knower-level better predicts ordinal comprehension than age.

We then compared the first model to one in which root regularity was excluded and ordinal was a categorical (rather than continuous) variable, to see whether something about the individual ordinals themselves better explains the data than morphological irregularity. The comparison reveals that this latter model (without regularity as a fixed factor) has a higher AIC (675.55), and does not differ significantly from the original ($\chi^2 = 0.3141, df = 1, p = 0.5752$). We therefore kept the original model as the final model, for which Table 6 summarizes the results.

Overall, the final model reveals main effects of ordinal, regularity and knower-level. The direction and implication of these effects should all be clear at this point. First, we see that the probability that a child comprehends a given ordinal decreases at the ordinal list progresses; i.e., that lower ordinals are more likely to be understood than high ones such as \textit{achtste} ‘eighth’. Second, we see that the morphological (ir)regularity affects the pattern of acquisition, such that regular ordinals such as \textit{tweede} ‘second, lit: twoth’ and \textit{vierde} ‘fourth’ are more likely to elicit a correct response than irregular \textit{derde} ‘third’. Finally, we see that an increase of cardinal knowledge also increases the likelihood of a correct response on the ordinal task. The comparison of the first two models further shows that knower-level matters more than age when it comes to comprehending ordinals.

### 4.3. Eerste ‘first’

So far, we have not gone into the data pertaining to \textit{eerste} ‘first’. As argued above, \textit{eerste} is a superlative, and not an ordinal (see also Barbiers 2007).
This conceptual difference led us to the hypothesis that its acquisition would differ from that of ordinals. For one, superlative acquisition in general typically starts at a much younger age, and for another, *eerste* is much more frequent than other ordinals. Therefore, the expectation is that scores on *eerste* ‘first’ would be higher for those reasons, as opposed to if it were considered an irregular ordinal. At first sight, children do seem to do better on *eerste* ‘first’ than on other ordinals at an earlier stage. Table 7 provides the outcome per knower-level on children’s correct responses only.

Table 7: Percentage of correct responses on *eerste* ‘first’ by knower-level

<table>
<thead>
<tr>
<th>Knower-level</th>
<th>Pre</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>% <em>eerste</em> ‘first’ correct</td>
<td>67%</td>
<td>56%</td>
<td>56%</td>
<td>100%</td>
<td>92%</td>
<td>100%</td>
</tr>
</tbody>
</table>

In contrast to children’s performance on the ordinals discussed above, where we see that children in the lower knower-levels are often unable to provide correct responses, here children actually do provide a correct response quite often. However, this does not mean that all children find the first card roughly half of the time; rather, we see a more bimodal distribution: some children systematically take the first card whereas others typically do not.

As it turns out, pre-to-three-knowers can be divided into two nearly equal-sized groups: children who did respond correctly when asked for the first in line (i.e., picked the first item, 14 out of 25 children) and children who did not (i.e., picked any card except the first, 11 out of 25 children). That this latter group constitutes floor performance on *eerste* ‘first’ needs no further explanation. However, that does not mean that the children in the former group understand the meaning of *eerste* ‘first’, as these children not only select the first when asked for the first, but also in 72% percent of the cases when asked for a different ordinal. In other words, these children also select the first card in response to trials requesting the second, third, fourth or eighth item. This indicates these children have a strong preference for the first card in line, and makes it difficult to assume children fully understand the meaning of *eerste* ‘first’; at the very best they are failing to infer that other ordinals are in a sense alternatives to *eerste* and therefore cannot refer to the first card in line. Note that this makes perfect sense if *eerste* is not part of the ordinal scale, but on a scale including say *middelste* ‘lit: middle–est’ and *laatste* ‘last’. For these forms,
it is possible to refer to one and the same object with an ordinal and the superlative: the last card could also simultaneously be e.g., the tenth in line. In this case, the first-preference could be ascribed to children’s failure to see that the same cannot be said for eerste ‘first’. These two groups of children (those with, and those without a preference for the first card) do not differ significantly in age (Mann-Whitney $U = 71.0$, $Z = -0.383$, $p = 0.702$, two-tailed) or gender (two-sided FET, $p = 1$) and there is no evidence that cardinal knower-level (pre-, one-, two- or three-knowers) makes a difference in terms of a ‘first-bias’ (Mann-Whitney $U = 69.0$, $Z = -0.533$, $p = 0.594$, two-tailed).

One other observation that has to do with children’s errors, is that children who give incorrect responses did do something crucially different in response to ordinal stimuli than cardinal ones: they nearly always took just one card when asked for an ordinal. Only two children packed multiple items on ordinal items, and they each only did so twice. This applies to children of all cardinal knower-levels, even those who were never able to identify ordinals correctly.

5. Discussion
5.1. Cardinals
We hypothesized that Dutch cardinal acquisition should not be qualitatively different from English. The results above are largely in line with this expectation, and offer support for the idea that the cardinal acquisition pattern is universal, providing evidence for all stages and observations within this pattern. First, we replicated the finding that children can typically count beyond what they can comprehend. Moreover, with textbook cases of children in every knower-level, our data support the idea that cardinal acquisition advances through different stages, in which children initially slowly acquire the exact meanings of cardinals één ‘one’ through vier ‘four’ one by one, and are then suddenly able to infer the exact meanings of the higher cardinals in their count list all at once. These findings can be added to the growing body of evidence for a universal pattern in cardinal development: children from different linguistic, cultural and educational backgrounds seem to map the exact meanings of cardinals to underlying representations according to the same pattern. This lack of variation strongly suggests that this process and the underlying cognitive representations are not only shared, but are also not qualitatively affected by, and are not artifacts of, the environment in
which children grow up. Rather, this is a fundamental property of human cognition.

Still, this does not mean that there is no variability between children. On the contrary, many studies have shown that children within a given sample vary greatly, and that there are also differences between groups. We hypothesized nonetheless that Dutch children should acquire cardinals similar to American children: as opposed to other studied languages, Dutch provides children with linguistic cues for discovering the meanings of numerals that are very comparable to English. However, our data show two noteworthy deviances. The first is that our sample includes only one three-knower. We take this to be accidental. The difference between the mean ages of two-knowers and four-knowers, who are two levels apart, is the same as the difference between stages that are just one level apart, i.e., between pre-knowers and one-knowers and one-knowers and two-knowers. This suggests that the three-knower stage is quite short (a claim that has been made elsewhere, see e.g., Almoammer et al. 2013), and that it is difficult to capture children who are (quickly) moving through this phase.

This brings us to the second deviance, namely that the children in our sample seemed somewhat slower than children reported in other studies. This was an unexpected result and the question is therefore how this finding could best be explained. We can only speculate at this point about what may or may not be the case. As mentioned above, this delay should not be attributed to linguistic factors like singular-plural marking, quantifier use or differences in the number words themselves, but could perhaps be linked to input (e.g., the frequency of numerals in child-directed speech). Unfortunately, we know of no studies that report such data in any language and our own data does not provide such information either. Another possible factor (similar to the one put forward in Almoammer et al. 2013) is cultural in nature, namely the education system. Dutch children typically do not go to school until age four; preschool for younger children is optional for most typically developing children. The three-year-olds we recruited attended day care centers without specific goals or programs for training children’s linguistic or numerical skills, whereas American preschools are educational institutions that strive to meet certain academic standards. It might also
be that Dutch preschoolers are less used to tasks such as ours.\textsuperscript{12} All of these differences might have put our participants at a disadvantage. This all remains open for future research, in which direct comparisons to other populations (Dutch and otherwise), should also be sought out. \textsuperscript{13} We reiterate, however, that the differences in timing are in itself not problematic: as pointed out in earlier research, the pattern of cardinal acquisition is deemed to be universal across languages and cultures, while the timing and duration of (the phases within) this pattern are notoriously variable.

5.2. Early stages of ordinal acquisition
Prior to this study, ordinal acquisition had only been studied minimally. Findings from previous studies suggested a number of possible factors that might influence ordinal acquisition, however, none of them properly and explicitly compared cardinal acquisition patterns to those for ordinals. Our data show that multiple factors are of influence when it comes to acquiring ordinals: age, cardinal knower-level, the place of the ordinal in a count list and the irregularity of the ordinal all play a role. We go into these factors (and especially the latter two) in section 5.3. Here, we focus on the earlier stages of acquisition, and the effects of age, cardinal knowledge and linguistic knowledge in these stages.

Children who have a limited understanding of cardinals also have difficulty with ordinals. The pre-to-three knowers in our study cannot be considered to have exact knowledge of any ordinal we tested: their scores are consistently low on all tested ordinals, and typically at floor for \textit{eerste}

\textsuperscript{12} We thank an anonymous reviewer for providing this suggestion. This reviewer also pointed out that our modified Give X task was generally more difficult than more standard versions of Give X. This would mean that no differences are expected when Dutch and English learners are subjected to the same task. However, as we will see in Chapter IV, this prediction is not borne out.

\textsuperscript{13} Hamilton, Plunkett & Schafer (2000) describe large and consistent differences in vocabulary development (both production and comprehension) between children aged 1;0–2;01 acquiring English in the US and the UK. Communicative Development Inventory (CDI) data show British children’s vocabulary development is delayed compared to the American group. The reason for this delay is uncertain, but the authors report that socio-economic status did not significantly affect vocabulary development in either group. They speculate about culture and cultural expectations and the influence of day care as potential causes instead. An anonymous reviewer points out that the CDI differences may also reflect differences in parents’ perception of their child’s vocabulary as much as the actual differences in their vocabulary, which makes the cross-cultural comparison even more difficult.
‘first’ as well. However, this does not mean that they know nothing at all or behave randomly. These children all have in common that they only selected one card when asked for any given ordinal. We take this to mean that children are able to use morphosyntactic cues to conclude that one and only one item is requested. Ordinals combine with singular nouns, and the DPs in our stimuli appeared in subject position, triggering singular agreement on the finite verb as well. Children at this age are able to comprehend the relevant inflectional morphology on nouns and verbs and are sensitive to number agreement (e.g., Polišenská 2010). However, we are not making any hard claims about the status of this knowledge with respect to its application to ordinals. Children may be responding to different parts of the stimulus. For example, perhaps they respond to the absence of plural marking on the noun (and agreeing verb) in the stimulus, or perhaps they take the whole DP into consideration.

Though the present study does not allow us to draw conclusions about how general their knowledge is, this question is testable. For example, we offered children a full DP in the stimulus (e.g., *De tweede eend mag mee. Kun je de tweede eend inpakken?* ‘The second duck can come. Can you pack the second duck?’). If children have genuine knowledge that ordinals are singular, then children should also provide one duck if explicit cues for number were missing from the stimulus, i.e., if the stimulus were *Kun je de tweede inpakken?* ‘Can you pack the second (one)?’. Note that *one* is obligatorily absent in Standard Dutch and the definite article appears with both plural nouns and common singular nouns. If children are responding to the subject-verb agreement, then children should do worse if the ordinal modifies the object. If they truly know that ordinals modify singular nouns, or if they truly know what a given ordinal means, they should not do worse on such trials.

That said, regardless of whether the pattern we found in our data reflects an answering strategy (i.e., on-the-spot-inference based on knowledge of the singular-plural distinction) or solid knowledge of ordinals, it does suggest that children are sensitive to cues from the input and are able to actively use this to infer meaning. Similar factors have, as mentioned in section 2, been proposed to play a role in acquiring cardinals, as well as in deciphering (flexible) mass and count nouns (Barner & Snedeker 2005, 2006; Carey 2009; Sarnecka et al. 2007). We suggest our ordinal data add evidence for the idea that children pick up on (a lack of) plural marking and use this to determine whether a DP refers to a mass, a set or an individual.
When children do start to give correct responses, this seems to happen on *eerste* ‘first’ first. Lower subset-knowers still have difficulty, but both four-knowers and CP-knowers performed at ceiling in response to *eerste* ‘first’ — even if their performance on subsequent ordinals was less robust. This finding would be consistent with the observation that *eerste* ‘first’ is a superlative in adult Dutch (cf. Barbiers 2007), and with the observation in our data that children were able to comprehend the superlative filler item in the vast majority of cases. This suggests that children at least have the option of interpreting *eerste* as a superlative and do not need any kind of ordinal rule to know what *eerste* means. Such a superlative analysis would also help to explain why some children exhibited some type of ‘first-bias’, i.e., gave the first item in line in response to all ordinals.\(^{14}\) It is possible that these children do understand the meaning of *eerste* ‘first’, but have yet to comprehend that, unlike with *last*, ordinals can be in competition with *first*. Another explanation has to do with frequency, *eerste* is roughly 50% more frequent than the following 19 ordinals combined (see section 2.3), and perhaps this overrides any effects of morphological irregularity.

However, if superlatives are easy, and *eerste* is extremely frequent, the question becomes why many lower subset-knowers were unable to interpret *eerste* correctly. Knowledge of cardinals and cardinality is not necessarily relevant from this perspective. One suggestion may be that *eerste* ‘first’ has less transparent degrees of comparison, making (acquisition of) the relationship between the positive and/or comparative and the superlative more complex. (This would mean the key factor here is not so much knower-level as it is age or more general development.) For one, *eer* ‘fore’ almost never occurs in modern Dutch, although it can be used as a complementizer in certain constructions like *eer je dat gedaan hebt*.

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\(^{14}\) Our data provide no real clues to help interpret this error in pre-to-three-knowers in any other fashion. We can rule out that children simply select the item closest from them, as the experimenter took care to distribute the cards such that the child could reach both ends of the line equally well. Even though this makes the ends of the line furthest away, a more general ‘furthest bias’ should have led to a more or less equal preference for the last card, which we do not see. The pattern might reflect a bias unrelated to ordinals, but what this could be and how it would work remains an open question. What is clear, however, is that the four-and-CP-knowers we tested did not seem to fall back on such a default response. Instead, many of the errors fell around neighboring numerals. These children likely have a different analysis of *first* and ordinals that excludes such a default strategy from a more pragmatic perspective of scalar implicature.
by the time you have done that’ and as a bound morpheme in words like
*eerdaags* ‘soon’/‘one of these days’, *eertijds* ‘in former times’, *eergisteren* ‘the
day before yesterday’ (Barbiers 2007). The comparative form *eerder* is used
in a wider range of contexts than the superlative, as it can be translated
in a number of different ways (as sooner, previously, before, earlier, rather,
more likely) not necessarily related to those of the superlative.

5.3. Later stages of ordinal acquisition
The data reveal that *tweede* ‘second’ and *vierde* ‘fourth’ soon follow the
acquisition of *eerste* ‘first’, but that it takes more time for children to
acquire irregular *derde* ‘third’ and regular higher ordinals. Our statistical
analysis suggests that two factors (in addition to a child’s age and knower-
level) play a role here: irregularity delays *derde*, and place in the count list
delays *achtste* ‘eighth’.

For one, poor behavior on *derde* ‘third’ (relative to *tweede* ‘second’
and *vierde* ‘fourth’) is related to its irregularity: whereas most ordinals are
derived from cardinals quite transparently, root allomorphy is present in
*derde* ‘third’ (the regular form would have been *driede* ‘lit: threeth’). The
question is why this irregularity should be a problem: if children hear
*derde* in the input, and they hear it more often than e.g., *vierde* ‘fourth’,
then they should be able to acquire this form lexically early on. That they
do not appear to do so, could either be explained by the weak hypothesis
or the strong hypothesis in section 2.4. The weak version entails lexical
learning of ordinals, in which transparency helps but is not crucial in
acquiring their meaning. *Derde* ‘third’ might be more difficult to store
because the form reveals no clues to its meaning. The strong hypothesis
entails rule-driven learning, in which children decompose the ordinal form
to arrive at its meaning. The question is to what extent our data reflect a
task-specific answering strategy or actual employment of a rule. Within
the context of the experiment, it is relatively easy for children to see both
the resemblance between *vier* and *vierde* (‘four’ and ‘fourth’) and their
differences (the extra morphology, singular agreement), and thus to apply
an answering strategy that fails when the cardinal root is not recognizable
(and there is also no lexical knowledge for the child to fall back on). Our
data do not allow us to see whether children are able to use or comprehend
ordinals outside the context of the task, but if children can use linguistic
structure within the task, this could be indicative of a bigger process in
acquiring these ordinals ‘in the wild’. We therefore take our data as evidence in favor of the strong hypothesis.

That ordinals are productive in adults is obviously uncontroversial, but we argue that ordinals actually start out that way as well. This is atypical: not only are most derivational affixes acquired at a later age (than inflectional morphology and ordinal morphology), the usual pattern observed in the acquisition of derivational morphology is that children initially store individual items, and later, after collecting sufficient evidence, analyze these items as complex morphological units and generalize over these examples to form a productive rule (Clark 2014).

However, the difficulty with derde ‘third’ suggests this item is not stored lexically as a single unit with a certain meaning, but that children actually make productive use of an ordinal rule (informally: cardinal + –de = ordinal) in order to acquire these ordinals.

Our claim here is that ordinals are formed by rules all along, and children must decipher the exceptions later. Put differently, in order to determine the meaning of an ordinal, the child first decomposes it: it applies the counting principles necessary to determine the meaning of the cardinal, and applies the relevant contribution of the ordinal (namely: picking out an individual, rather than the entire set) to that cardinal root. Such a strategy is supported by the fact that children would often count in response to an ordinal item, e.g., when asked for the vierde ‘fourth’, they would count to four and then pack the fourth. Obviously, such a strategy fails on derde because of the root allomorphy: there is no cardinal der. Moreover, for such a strategy to be plausible, the counting principles would have to be (largely) in place in order to be used for ordinals, and the timing in acquisition seems to reflect that.

5.4. Questions and tests for the current proposal

Note that the raw data above do not necessarily exclude the possibility that ordinals could be acquired in the same stepwise fashion that cardinals are acquired. After all, there is some evidence that eerste ‘first’ precedes at least tweede ‘second’, evidence that tweede precedes derde ‘third’ and that higher ordinals are acquired after lower ones. Moreover, we also see that children begin to acquire ordinals before cardinal acquisition is complete, suggesting that application of the relevant counting principles for ordinals comes in as children are still discovering how those for cardinals work. Hence, it could be that a tiered acquisition pattern is viable in some
languages, but is not (or at least not visible) in languages like Dutch, where morphology intervenes in this process. We think, however, that this may be unlikely.

For one, we would need some further details with respect to the hierarchy in responses: in cardinal acquisition, knowledge of *four* must entail knowledge of *three*, as understanding *three* is a conceptually necessary and more primary step compared to *four*. If ordinal acquisition were tiered, we would expect to find a similar hierarchy of knowledge, e.g., where knowledge of *vierde* ‘fourth’ would entail knowledge of *derde* ‘third’. Our data show that this is not the case and thus that the hierarchy is in fact absent.

A second and more important challenge for the view that ordinal acquisition is tiered, has to do with where to look next. Say it is true that there is a tiered pattern in ordinal acquisition, but that it just happens to be hidden in the Dutch case; then what language *should* exhibit a clearly tiered pattern? Is it more likely for such a tiered pattern to be visible in a language in which all ordinals are regular, or one in which irregularity is the norm? Under our analysis, it is the morphology that helps the child acquire the ordinals in the first place, eliminating the need for storage and step-by-step patterns: the child can simply apply the ordinal rule to all the numerals available in the count list. Perhaps then irregular cases would be better cases for tiered patterns, as children might then fall back on strategies used for acquiring cardinals (where they have no computation benefit to lean on, and must initially depend on storage). Having a highly irregular count list would also be more similar to the cardinal situation. The rule-based approach is by definition not applicable to cardinal acquisition: there are no morphological cues and there is no system to the lexical items denoting (lower) cardinal numerals, such that they can compute the meaning of these numerals; they must learn them one by one.

Fortunately, the role of morphology in ordinal acquisition is testable and the potential outcomes can easily be made concrete. If failure on irregular *derde* ‘third’ is indeed linguistic in nature, i.e., a result of not being able to apply a rule, we expect children who fail on such forms to perform better when the irregularity or opacity is resolved. In other words, if children actively derive ordinals via morphological rules, children who fail on *derde* should be able to pass on the ungrammatical yet regular *drie–de* (lit: ‘three–th’), as well as on the analytic form *auto drie* ‘car three’. Moreover, we expect (similarly to Miller et al. 2000) that children are quicker to acquire ordinals in a language with a transparent ordinal
system (e.g., French), than in a language in which ordinals (especially lower, more frequent ordinals) are less transparent (e.g., English). We also expect such differences to affect the pattern of acquisition. For example, French children should not experience more difficulties with troisième ‘third’ than with its neighboring ordinals. English children, however, must learn the rule via less frequent ordinals, and may therefore have difficulty with all of the first five ordinals. If English learners acquire regular ordinals before irregular ones, this would be evidence for rule-based learning; irregular forms would have to be acquired individually (and independently of their corresponding cardinal). If English learners acquire irregular ordinals before regular ones, this would point more in the direction of our weak hypothesis. In any case, the prediction is that more irregular forms lead to a longer acquisition process.

Recall that the existing literature tentatively points in this direction: American English speaking kindergartners performed relatively poorly on ordinals (Fischer & Beckey 1990; Miller et al. 2000), whereas the French speaking children (Colomé & Noël 2012) seemed to do better. The German children might also have a similar difficulty with dritte as the Dutch with derde, but Colomé & Noël (2012) mention no such troubles in the French-speaking group.

There is one final observation that we have so far left undiscussed. If it is indeed the case that children are applying a rule to derive ordinals, then why do CP-knowers, who obviously know higher cardinals, and who know regular low ordinals, fail on higher ordinals? Multiple explanations could account for this finding. For one, it might be they have not acquired a rule after all, but rely on frequency in the input or some other mechanism to acquire ordinals. This, however, would leave unexplained (i) why vierde ‘fourth’ is acquired at roughly the same time as tweede ‘second’, and (ii) why frequency is not enough for derde ‘third’, making this solution no less problematic.

Alternatively, this issue could be partially explained by inconsistency in performance. Children were tested on cardinal and ordinal items at two different times, and it might be the case that children who were classified as CP-knowers on one day performed worse on the ordinal testing day, and vice versa. That would mean, however, that ordinal performance was underestimated quite often, and more often than the reverse scenario (given that scores on acht ‘eight’ are so much higher than on achtste ‘eighth’). That suggests the inconsistency is not as big of a problem as the ordinal itself, especially if we consider that higher ordinals
were also more demanding for children in general: the further children have to count, the more taxing the task becomes, both in terms of working memory and in terms of motor skills (it is simply easier to collect three cards than eight cards). If we add in that ordinal comprehension requires yet another step (namely deriving ordinal meaning form the cardinal), then that again would increase the likelihood of an error in a situation when the child is already taxed. However, Chapter IV and V will show that general task demands do not sufficiently explain performance on higher ordinals, and that the difficulty is actually much more in line with what we see for cardinals: integrating ANS and OTS is demanding, and adding the ordinal derivation to that even more so.

6. Conclusion
This study compared the timing and pattern of acquisition of two numeral types in Dutch: cardinals and ordinals. The goal of the study was to investigate which factors play a role in ordinal acquisition, and to what extent these factors or this pattern differs from the cardinal situation. For cardinals, we expected the Dutch acquisition pattern to mirror the well-attested development found for other languages. There are no such robust patterns reported in the literature for ordinals, as little work has been done in the domain of ordinal acquisition to begin with. Going by the few studies we did encounter (cf. Fischer & Beckey 1990; Miller et al. 2000; Colomé & Noël 2012; Trabandt et al. 2015), we hypothesized that children’s comprehension of ordinals would not only be affected by children’s ages, but also by their knowledge and the place of the ordinal in the count list. Moreover, we expected language would play a role, both in the initial stages of ordinal acquisition (i.e., discovering that ordinals refer to an individual item rather than a set) as in the later stages (i.e., regular ordinals may help and/or irregular ordinals may hinder acquisition). Our results are in line with these expectations.

First, we found that the tiered pattern of cardinal acquisition also holds for Dutch, as it does for Japanese (Barner, Libenson et al. 2009; Sarnecka et al. 2007), Russian (Sarnecka et al. 2007), Slovenian (Almoammer et al. 2013), Saudi-Arabic (Almoammer et al. 2014), Chinese (Le Corre et al. 2016) and Tsimane’ (Piantadosi 2014). This supports both the knower-level theory and the claim that this development is universal and relies on shared cognitive representations and processes, rather than on cultural (educational) artefacts. Somewhat unexpectedly (as Dutch
does not differ from English in relevant ways here, e.g., with respect to its cardinals or number marking) we did find that Dutch children acquire cardinals somewhat later than their English-speaking peers. However, as various other studies point out, there are important differences between populations and individuals with respect to the timing and duration of the knower-stages. Further research is necessary to determine the nature and severity of the Dutch delay.

As for ordinals, we found that age and cardinal knowledge each contributed to children’s ordinal performance independently, and that ultimately cardinal knowledge better predicts ordinal comprehension than age. Children in pre-to-three-knower stages have at least understood that they should only take one card when asked for an ordinal. We suggest that children make use of morphosyntactic cues, i.e., that ordinals combine with singular nouns, to grasp the notion that an ordinal refers to an individual item rather than a set, which is a prerequisite for the ordinality principle. Later, as four-knowers or CP-knowers, children acquire exact meanings of ordinals. *Eerste* ‘first’, has a (slight) advantage in this process, given its status as a superlative (Barbiers 2007) and its sheer frequency. For true ordinals, we see effects of irregularity as well as the place of the ordinal in the count list (higher is harder): regular low ordinals are acquired before irregular *derde* ‘third’ and higher ordinals.

The difficulty with *derde* ‘third’ suggests that ordinals are not simply stored: if they were, the irregular ordinal should be acquired before less frequent, regular forms, and its irregularity would not necessarily be an issue. We argue that morphological compositionality is crucial in grasping ordinal meaning. In other words, children acquire ordinal meaning via an ordinal formation rule: they decompose the ordinal into the cardinal root and the ordinal suffix, and then use that structure to compute the meaning of the ordinal. This makes regularity crucial in acquisition (the strong hypothesis in section 2.4), rather than simply helpful (the weak hypothesis in section 2.4). If transparency was merely beneficial in acquisition, ordinal development could in principle start before children master cardinals; after all, nothing about the ordinal counting principles is more difficult than the cardinal ones. However, our data suggest being able to find *twee* ‘two’ is not nearly enough to decipher the meaning of *tweede* ‘second’, lit: ‘twoth’. If the acquisition is rule-based, ordinals have to be acquired as or after children become CP-knowers in order to have a sufficient foundation for their rule: without a full, exact
understanding of the cardinal root, it is impossible to determine the contribution of the suffix to that root to reach ordinal meaning.

One less straightforward outcome under this view is that *achtste* ‘eighth’ was noticeably harder than *tweede* ‘second’ and *vierde* ‘fourth’ for the children in our sample. If ordinal acquisition is rule-based, then the expectation would be that all regular ordinals are acquired at once. This delay of higher ordinals can be explained in part by the requirement that a child must be a reliable CP-knower in order to perform well on these items (some children who performed well on many ordinal items were classified as four-knowers), and in part by more general performance difficulties due to increasing task demands, but Chapters IV and V will show that this is likely related to the ANS and OTS.
Chapter III

Comparing comprehension and production*

1. Introduction

Over the past decades, serious efforts have been made to increase our understanding of how children develop numerical knowledge and number words. This endeavor has focused primarily on cardinal numerals, the development of cardinality, and on how numerical and linguistic knowledge interact. One domain in which this interplay might be particularly visible is the ordinal one: how and when are ordinal numerals such as *first*, *second* and *third* acquired?

Though few studies have attempted to answer this question, one recurrent and perhaps intuitive finding is that ordinals are acquired after cardinals (Colomé & Noël 2012; Miller, Major, Shu & Zhang 2000; Trabandt, Thiel, Sanfelici & Schulz 2015 and Chapter II). This delay could be (partly) motivated by conceptual difficulties, but the available evidence from these studies suggests that linguistic complexity also plays a role: ordinals are more difficult because they are morphologically complex, and the less transparent that complexity is, the more time the learner needs. Exceptions to the regular ordinal formation rule, e.g., irregular *derde* ‘third’ in Dutch, lead to more comprehension errors than regular forms such as *vierde* ‘fourth’ and *negende* ‘ninth’ (Chapter II), and learners acquiring a regular ordinal system like Chinese do so faster than learners of a more irregular ordinal list such as English (Miller et al. 2000). Though the conclusion might then be that a transparent relationship is (simply) beneficial to ordinal acquisition, the argument in Chapter II goes one step further: children use ordinal morphosyntax to acquire ordinal meaning.

However, the data they present for Dutch do not exclude other possible explanations: could it not be, for example, that children learn ordinals in a tiered and (at least initially) purely lexical fashion, similar to the way children acquire cardinals? The cross-linguistic differences in ordinal acquisition mentioned above could then be explained on the basis of whether ordinals are acquired without morphosyntax.

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* This chapter was adapted slightly from: Meyer, Caitlin, Fred Weerman & Sjef Barbiers (submitted). *Rules rule in Dutch L1 ordinal comprehension and production.*
of differences in the speed of cardinal acquisition. Such a lexical approach would also be more in line with what has been reported for the acquisition of derivational morphology: usually, children acquire complex forms as wholes and only decompose them into separate morphemes after having collected sufficient evidence for their complexity (Clark 2014). The claim for ordinals in Chapter II, on the other hand, is that children recognize and use the complexity to understand the meaning of the whole. Put differently, the typically observed pattern entails learning ‘from the outside in’, whereas the ordinal pattern entails acquisition ‘from the inside out’. The evidence for actual rule-based learning is somewhat limited, though, in part because the authors only tested comprehension. Whether the patterns found in comprehension are mirrored in production, and what this says about the rule(s) children follow as they acquire these synthetic ordinal forms (if there are indeed any rules to speak of at this early stage), has yet to be investigated.

The present study is the first to discuss ordinal production data, and compares the comprehension and production of ordinal numerals in Dutch monolingual children. It thereby contributes to our understanding of numerical development more generally and ordinal acquisition in particular. Our data confirm that ordinals are not simply acquired lexically and provide insight into how children develop the ordinal formation rule. We first go into what is known about ordinal acquisition, and what evidence there is to suggest that transparency plays a key role. Section 3 makes our hypotheses and predictions explicit. We describe the comprehension and production tasks (both in the spirit of Wynn’s 1992 ‘Give-a-Number’ task) we used to test these hypotheses in section 4 and discuss the results in sections 5 and 6, highlighting the differences and similarities between the two along the way. Section 7 concludes: rules rule in ordinal acquisition.

2. Ordinal acquisition and transparency

As mentioned in the introduction, little systematic evidence pertaining to the acquisition of ordinals exists. However, there is some work that sheds light on this process in a variety of languages: English, (Fischer & Beckey 1990; Miller et al. 2000), Chinese (Miller et al. 2000), French (Colomé & Noël 2012), German (Trabandt et al. 2015) and most recently Dutch (Chapter II). Taken together, these studies suggest that while there are language-specific effects that play a role, there are also some more general
tendencies that apply. Since those tendencies relate to the timing and pattern of ordinal acquisition relative to cardinal acquisition, it is important to briefly discuss cardinal acquisition first.

2.1 A brief note on cardinal development
Cardinal acquisition has been shown to proceed through a stepwise pattern in which children slowly grasp the meanings of the first four cardinals one by one (e.g., Le Corre & Carey 2007). At first, children may be able to recite a count list (although not necessarily an adult-like one from the start) and understand that cardinals refer to a numerosity, though they may not know which one. These children are referred to as ‘pre-knowers’ and are typically around two years old at this point. The first numeral to which they assign an exact interpretation is one. They then know that one means exactly one, and that other numerals must be more than one. Such a ‘one-knower’ will be able to give you, for example, one button if you ask the child for one button, but when asked for e.g., two buttons the child could give you any number of buttons higher than one. Next the learner acquires the meaning of two. A two-knower can give the appropriate number when asked for one or two, but when asked for three may give you three, four, or any other number higher than two. Similarly, three-knowers have exact knowledge of cardinals up to and including three, and it is at this point that they should realize that numerals refer to discontinuous quantities rather than, say, individuals and pairs, for one and two (Sarnecka 2015). In the next stage, children develop exact understanding of four, becoming four-knowers. Collectively, these knowers are known as ‘subset-knowers’, as they know a subset of the cardinals they can recite in a list (Le Corre van de Walle, Brannon & Carey 2006).

The next stage in cardinal acquisition is quite a step, as this is when children are able to infer the meanings of all the other cardinals in their count list and become fully competent counters, or ‘cardinal principle knowers’ (CP-knowers). At this point, children know at least three counting principles (see also Gelman & Gallistel 1978): the one-to-one correspondence principle (every cardinal belongs to one counted item), the stable order principle (the count list has a strict order), and the cardinal principle (the numerosity of the set is equal to the last number counted). When asked how many there are, CP-knowers count to determine the answer and repeat the last-named numeral. Children may reach this stage anywhere between their third birthday and some months after they turn
Though the start and duration of each stage varies considerably, this slow and sequential pattern of development is well-documented and has been shown to hold for learners from various linguistic backgrounds (e.g., Almoammer, Sullivan, Donlan, Marušič, Žaucer, O’Donnell & Barner 2013; Barner, Libenseon, Cheung & Takasaki 2009; Condry & Spelke 2008; Huang, Spelke & Snedeker 2010; Le Corre & Carey 2007; Le Corre, Li, Huang, Jia & Carey 2016; Piantadosi et al. 2014; Sarnecka 2015; Sarnecka, Kamenskaya, Yamana, Ogura & Yudovina 2007; Wynn 1992, and Chapter II). We refer the reader to Sarnecka (2015) for a detailed and recent overview of children’s development of numerical knowledge.

2.2 Ordinal development

The cardinal acquisition pattern is immediately relevant to the ordinal one, not only on an empirical level (as mentioned above), but also on a conceptual one: the one-to-one correspondence principle and the stable order principle are not only necessary to determine how many in a set (i.e., cardinality) but also which one in a line or progression (i.e., ordinality). The conceptual difference between answering those two questions is that the cardinality principle needed in the first situation is exchanged for the ordinality principle in the latter: the last count then represents not the cardinality of the set, but the ordinality of that individual item. Meyer et al. (2016) initially speculate that it should not be more difficult for children to learn to apply the ordinality principle than the cardinality principle, reasoning that picking out an individual from a set (ordinality) is not conceptually more complex than representing the entire set (cardinality).

However, what they and others observe in acquisition is that ordinals are in fact acquired later than cardinals. Children of various ages can count further using cardinals (Miller, Major, Shu & Zhang 2000) and kindergarteners perform better on cardinal comprehension tasks than on ordinal ones (Fischer & Beckey 1990; Colomé & Noël 2012; Chapter II). Moreover, from pretest data described in Matthei (1982) and Hamburger & Crain (1984) we can conclude that at the age at which most children should be fully competent counters, roughly one in five children still fails to demonstrate knowledge of second and third. The ‘Give Me’ type comprehension task (cf. Wynn 1992; Colomé & Noël 2012) in Chapter II directly shows that at least some cardinal knowledge must be in place before ordinal acquisition begins. Children who have yet to acquire the first four cardinals also fail to grasp the meaning of (any) ordinals; such
pre-to-three-knowers are only able to demonstrate that ordinals refer to individuals, not sets. In other words, when asked for the fourth, these children grab only one item (and not, for example, four) though they do select the incorrect one. These difficulties do not suddenly disappear when children acquire the cardinal principle, either, as even children classified as CP-knowers often have difficulty on the ordinal trials in this study.

Cardinal and ordinal acquisition not only differ with respect to timing, but also with respect to the pattern that we observe. Whereas lower cardinals are acquired in a tiered or stepwise pattern (i.e., children who have mastered four also have an exact understanding of three), the claim in Chapter II is that regular ordinals are acquired at once (at least conceptually — while some children have difficulty with high ordinal achtste ‘eighth’ they argue this is due to performance issues) and irregular ordinals follow later. They find that Dutch four-knowers and CP-knowers were able to find at least the eerste ‘first’, and usually also the tweede ‘second, lit: two—th’ and vierde ‘fourth’, while comprehension of the irregular form derde ‘third’ seemed to develop later, in some children even after (regular) higher ordinals such as achtste ‘eighth’ and negende ‘ninth’.

The acquisition pattern they describe can be summarized as follows:

(i) Children use morphosyntactic cues (such as the fact that ordinals combine with singular nouns, whereas most cardinals combine with plurals) to discover that ordinals refer to individuals, not sets.

(ii) Children, when they are at least four-knowers, acquire eerste ‘first’ first. This form is acquired relatively early for three reasons. It does not require true counting competence, it is roughly 50% more frequent than tweede ‘second’ through twintigste ‘twentieth’ combined, and it has been shown to be a regular superlative (rather than an ordinal) in Dutch (Barbiers 2007).1

(iii) Children acquire the ordinal formation rule (informally: cardinal + suffix = ordinal). This leads to (near) ceiling performance on at least

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1 Though eerste ‘first’ is not an ordinal, we are including it in the developmental pathway for ordinals because it does fulfill that function in practice: it denotes the beginning of a line. As a result, the claim is not that the acquisition of eerste is related to ordinal acquisition and does not influence it. The acquisition of eerste simply precedes that of ordinals due to its frequency and relative simplicity (no counting is involved).
low, regular ordinals such as *tweede* 'second, lit: two–th' and *vierde* ‘fourth’.

(iv) Extra-linguistic factors influence performance on higher, regular ordinals: the further one has to count and maintain one-to-one correspondence, the more demanding the task becomes. Knowledge of higher ordinals is by definition limited to CP-knowers only, since children who cannot count beyond *four* cannot be expected to count to higher ordinals either.

(v) Performance on irregular *derde* ‘third’ follows at some point after acquisition of the rule. Note that this might be before or after performance on higher ordinals improves.

Chapter II argues that children’s failure to comprehend irregular *derde* ‘third’ while being able to find other (higher) ordinals shows that children do not store individual ordinals lexically (at least not with an interpretable meaning), but derive them via a morphological rule. The hypothesis is that children acquire ordinals via rules from the very beginning, first applying the regular counting principles to the cardinal root, and then adding on the semantic contribution of the ordinal suffix (namely, to pick out an individual, rather than denote the cardinality of a set). Such a strategy fails in irregular cases, where the root allomorph is not recognized as such. (Though we do not say so literally, it appears children recognize *der* in *der–de* should be a cardinal, but do not know to which cardinality it refers; children would sometimes look at their fingers and ask *wat is der* ‘what is *der*’ or count out loud and say that *der* is not there).

This stance is not exactly uncontroversial, as it goes against the typical patterns in acquiring morphology, both derivational and inflectional. Children are known to be ‘little inflection machines’, demonstrating knowledge of inflectional elements from the earliest stages of production, i.e., from around 18 months on (Wexler 1998, p. 43), especially if the inflections are regular and salient (see Polišenská 2010 for discussion). By the age of three, children have developed clear knowledge of number marking on nouns, and number and person on verbs, though their production is far from perfect (see e.g., Polišenská 2010; Van Wijk 2007; Wood, Kouider & Carey 2009). The most persistent errors occur in irregular forms, and are typically overgeneralization errors that follow a so-called change for the worse or U-shaped pattern of development. The
classic example is the production of English past tense: children may initially say went correctly, then *goed then also temporarily occurs in their production after acquiring the –ed rule, and ultimately, this overgeneralized form disappears (e.g., Marcus, Pinker, Ullman, Hollander, Rosen & Xu 1992; Pinker 1999). Crucially, inflectional morphology is acquired relatively early on, and in a rule-based fashion.

By contrast, derivation is not as well-studied as inflection in acquisition, but evidence from adults suggests that storage often beats computation in adults, for whom it has been claimed that derived forms are more likely to be lexicalized because the affix changes the word class, whereas regular inflections are more likely to be processed combinatorially (e.g., Clahsen 2006; Leminen, Leminen, Kujala & Shtyrov 2012). This makes it unsurprising that the limited work on child language does not seem to provide evidence for a rule-based approach or U-shape in the acquisition of derivation. Quite the contrary: the typical pattern involves children learning individual items lexically, only to generalize over these examples and form a productive rule after they have accumulated sufficient evidence for their morphological complexity (Clark 2014). Put differently, whereas children typically learn complex forms as a whole before being able to decompose them into separate morphemes, the ordinal situation involves children using the parts to arrive at the meaning of the whole. This process comes sooner for some affixes than for others; while agentive –er in English is productive in three-year-olds, most derivational affixes are acquired during elementary school and the timing depends on the identifiability and transparency of both the root and the affix, as well as on productivity (Clark 2014). For example, allomorphs of the Dutch diminutive are acquired between the ages of five and nine (Boersma, Rispens, Weerman & Baker, submitted), depending on the phonological complexity of the root and frequency of the affix. All in all, this makes the claim in Chapter II quite strong. This requires further investigation, preferably with support from production data.

3. Hypotheses and predictions
The present study aims to address some open issues that would further test the hypothesis put forward in Chapter II: are ordinals in fact acquired in a rule-based fashion and what might the nature of this rule be? We look at different types of ordinals, not only in comprehension, but also in production, which allows us to investigate to what extent difficulties in
comprehension are also reflected in production. As in Chapter II, the focus is on Dutch. Though we have already discussed some relevant properties of the Dutch ordinal system, Table 1 provides an overview of the first twenty cardinals and ordinals in Dutch, including their frequencies in the Corpus Gesproken Nederlands ‘Spoken Dutch Corpus’ (Oostdijk 2000). The CGN contains roughly 9 million words in 1000 hours of speech files from the Netherlands and Flanders; the frequencies represent absolute occurrences per million words.

Table 1: Cardinal and ordinal formation in Standard Dutch. Frequencies, taken from Chapter II, reflect absolute frequencies per million words in the Spoken Dutch Corpus (Oostdijk 2000).

<table>
<thead>
<tr>
<th>#</th>
<th>Cardinal</th>
<th>Ordinal</th>
<th>Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>één</td>
<td>eer-ste</td>
<td>1214.11</td>
</tr>
<tr>
<td>2</td>
<td>twee</td>
<td>twee–de</td>
<td>387.33</td>
</tr>
<tr>
<td>3</td>
<td>drie</td>
<td>der–de</td>
<td>151.44</td>
</tr>
<tr>
<td>4</td>
<td>vier</td>
<td>vier–de</td>
<td>69.89</td>
</tr>
<tr>
<td>5</td>
<td>vijf</td>
<td>vijf–de</td>
<td>40.22</td>
</tr>
<tr>
<td>6</td>
<td>zes</td>
<td>zes–de</td>
<td>37.00</td>
</tr>
<tr>
<td>7</td>
<td>zeven</td>
<td>zeven–de</td>
<td>17.00</td>
</tr>
<tr>
<td>8</td>
<td>acht</td>
<td>acht–ste</td>
<td>10.78</td>
</tr>
<tr>
<td>9</td>
<td>negen</td>
<td>negen–de</td>
<td>9.67</td>
</tr>
<tr>
<td>10</td>
<td>tien</td>
<td>tien–de</td>
<td>17.89</td>
</tr>
<tr>
<td>11</td>
<td>elf</td>
<td>elf–de</td>
<td>7.78</td>
</tr>
<tr>
<td>12</td>
<td>twaalf</td>
<td>twaalf–de</td>
<td>9.67</td>
</tr>
<tr>
<td>13</td>
<td>der–tien</td>
<td>der–tien–de</td>
<td>8.22</td>
</tr>
<tr>
<td>14</td>
<td>veer–tien</td>
<td>veer–tien–de</td>
<td>8.56</td>
</tr>
<tr>
<td>15</td>
<td>vijf–tien</td>
<td>vijf–tien–de</td>
<td>8.44</td>
</tr>
<tr>
<td>16</td>
<td>zes–tien</td>
<td>zes–tien–de</td>
<td>11.22</td>
</tr>
<tr>
<td>17</td>
<td>zeven–tien</td>
<td>zeven–tien–de</td>
<td>11.22</td>
</tr>
<tr>
<td>18</td>
<td>acht–tien</td>
<td>acht–tien–de</td>
<td>11.78</td>
</tr>
<tr>
<td>19</td>
<td>negen–tien</td>
<td>negen–tien–de</td>
<td>14.56</td>
</tr>
<tr>
<td>20</td>
<td>twin–tig</td>
<td>twin–tig–ste</td>
<td>14.67</td>
</tr>
</tbody>
</table>

As in English, ordinals in Standard Dutch are derived by adding a suffix to the rightmost part of the cardinal. This suffix is –de for most ordinals.

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2 We report CGN data because ordinals hardly ever occur in child-directed speech and child production in the Dutch corpora in CHILDES (MacWhinney 2000).
ending in a numeral under 20 (low ordinals, but also e.g., tweehonderddertiende ‘two hundred thirteenth’); all other ordinals are formed with –ste. There are three exceptions that we discussed in passing earlier: eerste ‘first’, derde ‘third’ and achtste ‘eighth’. Again, we take eerste ‘first’ to be a superlative, and not a product of root allomorphy plus the higher ordinal suffix –ste (see Barbiers 2007 for the relevant observations and arguments). The other two cases are true irregularities: derde (not *drie–de) is a case of root allomorphy, while achtste takes –ste (not *acht–de).

Obviously, the minimal expectation of the present study is to replicate (where applicable) the findings in Chapter II. The further goals are to answer the questions that follow from earlier work, the most urgent of which is to what extent a rule really is at play, or whether there are other conceptual or frequency difficulties that influence children’s behavior. One way to test this is to include the regularized yet ungrammatical form *driede ‘threeth’ in the comprehension task. If children perceive the morphological structure of ordinals, then the difficulty attested in Chapter II for derde ‘third’ should not appear in the regularized form driede ‘threeth’, despite its ungrammaticality and its absence from the input. Moreover, if children are actively (productively) using a rule, we also expect this regularized form to arise in children’s production. In other words, children who are unable to comprehend derde but do understand the regular neighbors tweede ‘second’ and vierde ‘fourth’ are expected to produce the regularized form *driede ‘three–th’. If they do not, any effects found in the comprehension task may simply reflect some (task-specific) answering strategy. Obviously, we expect that children who cannot find the derde ‘third’ item in a comprehension setting, will not use that form when asked to describe the third item in line in an elicited production setting.

We also expect to see some sort of rule effect in the case of achtste ‘eighth’, and the use of the suffixes children use there and elsewhere. It is possible for children to be lenient or ‘sloppy’ about their rule in comprehension situations, especially in a test setting such as in the ‘Give a number’: the task repeatedly asks for different numerals, and so children may be able to infer the meaning of achtste ‘eighth’ within this particular context. However, their production might reveal more. The form *achtde would provide direct evidence for a rule in which only –de is considered an ordinal suffix (at least for lower ordinals), whereas achtste could either be
lexically stored, or the product of a rule in which –ste (also) plays a role (e.g., where the rule specifies for which root each suffix applies).

One might be inclined to entertain a similar type of reasoning for eerste ‘first’ as for derde ‘third’ and achtste ‘eighth’, arguing that a form such as *eende ‘one–th’ or *eenste ‘one–est’ may appear in production. However, Chapter II only mentions anecdotal evidence for *driede, not for regularized ordinal alternatives to eerste ‘first’. Moreover, it is difficult to formulate precise predictions for eerste and its regular counterparts, given that eerste is a superlative whereas *eende ‘one–th’ and *een–ste ‘one–st’ are ordinals — ordinals that should not be possible if we follow Barbiers (2007), who considers the feature composition of één ‘one’ to be incompatible with regular ordinal formation in Dutch. Nevertheless, one possible outcome would be clear: if children are able to interpret *eende ‘one–th’ or *eenste ‘one–st’ as the first in line, this means they are decomposing this form on the spot: because these forms are impossible in adult Dutch, they are absent from the input, and thus their meaning could not be determined in any other way.

From the above, the reader may conclude that we are pitting two potential challenges against each other: root allomorphy (as in derde ‘third’) and suffix allomorphy (as with achtste ‘eighth’). Note that the challenges of each of these forms are different in comprehension and production. In comprehension, it may be easier to ‘ignore’ the irregularities in suffix as long as the relationship with the cardinal base is transparent (i.e., maybe achtste is easier than derde) whereas in production, the difference in suffix may be less salient than the root allomorphy in derde, which is also much more frequently encountered. Hence, it may be that the challenge in derde is overcome more quickly in production than the irregularity of achtste.

In short, our study is set up to test whether children acquire ordinals in a rule-based fashion along the lines of Chapter II, adding insight from production data. Ordinals should be acquired after children acquire cardinals, and after the superlative eerste ‘first’. Children should learn regular forms simultaneously, though higher ordinals may follow later for non-linguistic reasons. But the key focus will be on irregular forms: we expect to find children who have difficulty comprehending and/or producing the irregular form derde ‘third’ (i.e., *driede), and difficulty producing achtste ‘eighth’ (i.e., saying *achtde instead). More generally, we expect children to comprehend the necessary forms before they can produce them.
4. Method

The studies on cardinal and ordinal acquisition discussed above all make use of some variation of the ‘Give-a-Number’/‘Give me’ paradigm (Wynn 1992), while Colomé & Noël (2012) adapted this for eliciting production data as well (‘Tell me’). We took a similar approach, testing all children on both comprehension (cardinals and ordinals) and production (ordinals only).

4.1 Participants

A total of 68 typically-developing monolingual Dutch children (37 boys, 31 girls; ages: 39–72 months, $M = 58.90$, $SD = 8.53$) could be included in the results. We excluded an additional 15 children (11 male, 4 female; ages: 37–72 months, $M = 45.13$, $SD = 10.36$) because they did not complete the entire task. The excluded children (of whom 11 were under the age of four) were typically unwilling or unable to provide any (relevant) responses in the first session, which tested production.

4.2 Materials and procedure

We made use of the materials developed and discussed in Chapter II, adapting them such that they could be used to test both comprehension and production in two separate sessions. The production task focused on ordinals only, testing *eerste* ‘first’ through *vierde* ‘fourth’, *zesde* ‘sixth’, *achtste* ‘eighth’ and *negende* ‘ninth’, plus the indefinite ordinal *laatste* ‘last’. Each ordinal was elicited three times, leading to a total of 24 items in this session. The comprehension task, which we expected to be easier and faster to administer, included the ordinals tested in production, their corresponding cardinals (to assess a child’s knower-level), plus the ungrammatical but regular forms *eende* ‘oneth’, *eenste* ‘onest’, and *driede* ‘threeth’. Here, too, each numeral was tested three times, bringing the total session to 54 items. We administered the production sessions first to ensure the comprehension items could be of no influence on the production items (i.e., so children would not be ‘inspired’ by the comprehension session). Sessions were administered within one week of

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3 We did not test more ordinals because it would have made the test too long, especially for the comprehension session. We chose the first four ordinals to be able to watch for stepwise patterns (as with cardinals), *achtste* ‘eighth’ because it is irregular, *negende* ‘ninth’ as its regular neighbor, and *zesde* ‘sixth’ as an intermediate place between low and high. We thus used an improved/elaborated version of the original Chapter II list.
each other. See the Appendix for a full list of stimuli and a description of the test orders.

At the beginning of the session, the experimenter familiarized the child with the procedure and the materials, by means of a short introductory story in which a monkey puppet named Jaap is going on a trip. The story describes how of Jaap’s things (laminated cards with images of everyday objects and animals on them) are so eager to join him, that they are getting in line to jump into his suitcases (two metal toy suitcases). The monkey knows he will not be able to bring everything, so the child is asked to help him pack the correct items from the line into the suitcases. In the production session, the monkey knows what he wants to bring but doesn’t know how to say it, so the child ‘teaches’ the monkey how to ask for the correct items by completing the answer to a question, such as in (1). The experimenter urged children to count out loud and use their finger while counting in order to reduce the errors caused by imperfect counting. Children were also allowed to recount (“check and make sure”). Children who simply counted and repeated the last count (e.g., een, twee, drie, vier — vier ‘one, two three, four — four’) received an extra prompt: Dus hij is de…? ‘So he is the…?’ Note that the stimulus and the extra prompt included a definite determiner, making a response with an analytic ordinal (e.g., beer drie ‘bear (number) three’) ungrammatical (cf. Colomé & Noël 2012 for the use of analytic ordinals in French-speaking children).

(1) De aap zegt dat deze beer mee mag.
    The monkey says that this bear with may.sg.
    ‘The monkey says that this bear gets to come.’

Welke beer is dit / Op welke plek staat deze beer?
Which bear is this / On which place stands this bear?
(Op de / Hij is de…)  
(On the / He is the…)  
‘Which bear is this? / Which place is this bear in? (The…)

In the comprehension session, the monkey puppet thinks he has learned how to ask for the right things and the child’s job is to pack what the puppet asks for, such as één camera ‘one camera’ or het derde konijn ‘the
third bunny’. Literal examples of stimuli are given in (2) and (3) for cardinals and ordinals, respectively. In an effort to keep the game-play natural, formulaic variation did occur, but typical comprehension stimuli offered the numeral as part of a full subject DP. When necessary, the numeral was repeated with either a noun (in the case of cardinals, e.g., *negen ballonnen* ‘nine balloons’) and/or a definite article (in the case of ordinals, e.g., *de tweede (slee)* ‘the second sled’).  

Children were allowed to ‘count and make sure’ their responses were correct.

(2) Er mogen acht stiften mee. Kun je acht stiften
   There may.PL eight markers with. Can you eight markers
   (tellen en) inpakken voor Jaap?
   (count and) pack for Jaap?
   ‘Eight markers get to come. Can you (count and) pack eight markers
   for Jaap?’

(3) Jaap zegt dat de zesde jas mee mag. Kun je de
   Jaap says that the sixth coat with may.SC. Can you the
   zesde jas (vinden en) inpakken voor de aap?
   sixth coat (find and) pack for the monkey?
   ‘Jaap says that the sixth coat gets to come. Can you (find and) pack
   the sixth coat for the monkey?’

The pictures we used for ordinal items (both sessions) had clear fronts or faces in order to emphasize the direction of the line, and all items in that line were identical (so the child could not select an object on the basis of any other distinguishable property). The number of items in line depended on the cardinal or ordinal in question: the lowest numeral trials (*one, two, first* and *second*) all occurred with four cards in line; numerals *three, four, third* and *fourth* with six cards, and the higher numeral conditions consisted of ten cards. We presented items in one of eight (comprehension) or two (production) pseudo-random orders within each session, which we counterbalanced between participants. Both sessions started with two practice items (in which children had to find or name a certain object

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*Note that N-ellipsis in the ordinal case should not be an issue. For one, the child always heard the full DP in the initial stimulus. For another, N-ellipsis occurs naturally in child speech from at least 1;8 on, using licensors such as (but not limited to) cardinals, quantifiers superlatives and *eerste* ‘first’ (Sleeman & Hulk 2013).*
vooraan ‘at the front’ and achteraan ‘at the back’ of the line), and ended with a counting session, in which children were asked (to try) to recite the cardinal and then ordinal count list to thirty (thirtieth). Children were allowed to use the cards to perform these counting tasks.

Before looking at ordinal knowledge, we first determined the cardinal knower-level for each child using the knower-level estimation tool provided by Lee & Sarnecka (2010a,b) and the criteria described in e.g., Le Corre & Carey (2007). According to these criteria, children had to provide the correct number of cards for a given numeral at least two out of three times when asked for that numeral, and provide that number of cards no more than once in response to a different numeral. Applying the criteria and the tool yielded the same outcome in all but two instances, where we opted to give the child the benefit of the doubt. Children’s ordinal knowledge was determined as in Chapter II, in that we only took children’s correct responses into account.5

5. Comprehension
Table 2 displays the ages of the children at each cardinal knower-level and their group performance on the counting task, for which the highest count of the two sessions was used for each child. Two CP-knowers (children who mastered the cardinal principle) did not want to perform the counting task; there is no counting data available for them. All but one child recited a count list higher than ten (which was the maximum number of cards on the table for any given trial).

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5 As mentioned in Chapter II, since the acquisition pattern of ordinals does not appear to be tiered in the way cardinal acquisition is, it is difficult to determine what an error means for the ordinal the child provided incorrectly and whether (and how) such an error should be weighted. In the cardinal situation, giving three items when asked for six entails the child does not understand either numeral (and all numerals in between). Giving the sixth item when asked for the third, however, does not imply the child will not understand fourth, fifth or even sixth — the only clear problem is third.
Table 2: Overview of the ages and count lists per cardinal knower-level attested in our sample. Age ranges and means are given in years (year:month) and months, the SDs in months only.

<table>
<thead>
<tr>
<th>Levels</th>
<th>n</th>
<th>Age Range</th>
<th>Age Mean</th>
<th>Age SD</th>
<th>Count List Range</th>
<th>Count List Mean</th>
<th>Count List SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-knowers</td>
<td>2</td>
<td>3;3–4;0 (39–48)</td>
<td>43.5</td>
<td>6.36</td>
<td>10–16</td>
<td>13</td>
<td>4.24</td>
</tr>
<tr>
<td>4-knowers</td>
<td>6</td>
<td>4;0–5;10 (48–70)</td>
<td>55.67</td>
<td>7.61</td>
<td>17–20</td>
<td>18.5</td>
<td>1.05</td>
</tr>
<tr>
<td>CP-knowers</td>
<td>60</td>
<td>3;6–6;0 (42–72)</td>
<td>59.73</td>
<td>8.19</td>
<td>6–30</td>
<td>26.05</td>
<td>5.77</td>
</tr>
</tbody>
</table>

These data are in line with what is described in Chapter II (Table 3), where we also lacked three-knowers and found similar mean ages among two-, four- and CP-knowers (namely 44.5, 52.1 and 59.6 months, respectively). Note, however, that the overall mean age in this sample is higher: 59.5 months (SD = 8.1) versus 52.4 months (SD = 10.6).  

5.1 Results

We excluded three children from further analysis on the basis of their performance: both two-knowers and a four-knower. One of the two-knowers and one of the four-knowers in our sample lacked specific ordinal knowledge altogether. While these children did only give one card in response to ordinal stimuli, indicating that they were at least not assigning a cardinal interpretation to ordinals, the two-knower appeared to always pick a random card while the four-knower always selected the first card (see the first-bias reported in Chapter II). The third child we excluded (a two-knower) often gave ordinal responses to cardinal trials (e.g., picking the fourth card when asked for four), in addition to ordinal responses on ordinal trials (passing on all ordinal items except those for derde ‘third’ and achtste ‘eighth’).  

The remaining 65 four-knowers and CP-knowers provided correct responses to at least some ordinal trials (Figure 1). Errors in ordinal comprehension were generally rare, and nearly all errors were cases where children selected the incorrect card, but not an incorrect number of card;  

6 Though we did test younger children, many of them were excluded for not being able to perform on the production task.

7 This behavior may indicate an underestimation of this child’s cardinal knowledge, and may indicate a task effect (i.e., the similarity of the different types of trials may have influenced this participant’s performance) but we have no other means at our disposal to determine her knowledge otherwise.
they knew to select just one. As in Chapter II, a cardinal answer in response to an ordinal trial (e.g., giving four cards when asked for the fourth) was extremely rare, occurring on only five occasions (out of over 3500 trials in our dataset). Figure 1 shows the distribution of correct responses.

Figure 1 shows that CP-knowers nearly always provide correct responses on ordinal comprehension items. Wilcoxon signed ranks tests reveal a significant difference between the irregular form derde ‘third’ and tweede (\(Z = -4.125, p < 0.001\)) and derde and vierde (\(Z = -4.128, p < 0.001\)), but not between *driede and tweede or vierde. In addition, all 18 CP-knowers who cannot find the derde ‘third’ (30%) are able to find the driede ‘threeth’. Irregular achtste ‘eighth’ differs from derde ‘third’ (\(Z = -3.430, p = 0.001\)) and zesde ‘sixth’ (\(Z = -2.310, p = 0.021\)) but not from negende ‘ninth’, nor do zesde and negende differ significantly. We also see that CP-knowers do well on indefinite ordinal laatste ‘last’ and the ungrammatical yet regularized trials. Performance on regularized ordinals for eerste ‘first’ (eende ‘oneth’, with the ordinal suffix –de, and eenste ‘onest’, with the suffix for superlatives and ordinals –ste) are at ceiling. The four-knowers have difficulty across the board, with none of the ordinal pairs having significantly different mean proportions of correct responses, although one would expect (perhaps with a larger sample) that derde ‘third’ and higher ordinals would evoke significantly lower scores.
These group results fail to take certain factors and random effects into account, however. We used R (R Core Team 2016) and lme4 (Bates, Maechler, Bolker & Walker 2015) to fit a generalized linear mixed-effects logistic regression model to the data described above, minus those items that we included above to be complete, but strictly speaking do not fit into an analysis regarding ordinals, namely those forms that are considered superlatives (eerste ‘first’ and its regularized counterparts *eende, and *eenste, as well as laatste). In other words, we tested all regular ordinals tweede, derde, vierde, zesde, achtste, negende and *driede (‘second’–‘fourth’, ‘sixth’, ‘eighth’, ‘ninth’ and *‘threeth’). We also excluded all subset-knowers, as there are too few of them to analyze properly and their performance is clearly below that of CP-knowers. For the ordinals included in the model below, four-knowers provided a correct response significantly less often than CP-knowers (Mann-Whitney \(U = 43.5, Z = -2.842, p = 0.004\), two-tailed).

Our statistical analysis takes the procedure described in Chapter II as a starting point, but with a few differences. We cannot take knower-level into account, for example, as we are focusing on CP-knowers here. In addition, we coded achtste ‘eighth’ as irregular (Chapter II treats it as regular; that data left no room for testing the effect of –ste, since achtste was effectively the only higher ordinal in the set) within the factor regularity.8 One further difference is that we made use of a more elaborate random effects structure, including by-subject random intercepts with slopes for ordinal (place in the count list) as a continuous factor and by-trial random intercepts with slopes for age in months. We included as fixed factors ordinal, regularity (i.e., whether the ordinal numeral was regular, as for e.g., zesde ‘sixth’, or irregular, as in the case of derde ‘third’), and age in months, as well as interactions between age and ordinal, and age and regularity. The dependent variable in all models was whether a child’s response was correct or incorrect.9 Continuous factors were centered; categorical factors were coded with explicit contrasts before analysis. No outliers other than those described above were removed.

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8Note that it is impossible to tease apart the effects of root and suffix allomorphy directly. While we did test a regularized counterpart for derde ‘third’ (namely *driede), we did not test a regularized counterpart for achtste ‘eighth’. Moreover, these properties do not occur anywhere besides derde and achtste, and so these factors cannot be analyzed apart from the place in the ordinal count list.

9Including ordinal as a categorical factor led to convergence errors. We opted to simplify the model rather than eliminate the random slopes completely.
To determine whether the place in the ordinal list better explains the data than morphological irregularity, we compared this model to one in which regularity was excluded and ordinal was a categorical (rather than continuous) variable. The prediction is then that though this new model has more parameters and thus should explain more variance, most of the variance is already explained by the existing model. This led to convergence warnings, and the comparison reveals, as in Chapter II that this latter model (without regularity as a fixed factor) has a higher AIC (470.09 compared to 376.94) and BIC (470.09 compared to 438.61). We therefore maintain the model as initially constructed. Table 3 describes the results of this final model.

Table 3: Result summary for correct responses on ordinals for 2, 3 (including *driede* 'threeth'), 4, 6, 8 and 9: β coefficient estimates, confidence intervals, standard errors, associated Wald’s z-score and significance level (p) for all predictors in the analysis. Formula: Correct ~ (OrdinalContinuous + Regularity) * AgeInMonths + (1 + OrdinalContinuous | Subject) + (1 + AgeInMonths | Trial).

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimate</th>
<th>CI</th>
<th>SE β</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.091</td>
<td>4.331 – 7.851</td>
<td>0.898</td>
<td>6.783</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ordinal</td>
<td>0.228</td>
<td>-0.381 – 0.838</td>
<td>0.311</td>
<td>0.734</td>
<td>0.4627</td>
</tr>
<tr>
<td>Regularity</td>
<td>4.211</td>
<td>2.897 – 5.525</td>
<td>0.670</td>
<td>6.282</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age</td>
<td>0.141</td>
<td>0.0183 – 0.263</td>
<td>0.063</td>
<td>2.252</td>
<td>0.0243</td>
</tr>
<tr>
<td>Ordinal * Age</td>
<td>-0.033</td>
<td>-0.071 – 0.005</td>
<td>0.019</td>
<td>-1.722</td>
<td>0.0851</td>
</tr>
<tr>
<td>Regularity * Age</td>
<td>-0.036</td>
<td>-0.154 – 0.079</td>
<td>0.060</td>
<td>-0.361</td>
<td>0.5284</td>
</tr>
</tbody>
</table>

Overall, the model reveals a main effect of the (ir)regularity of the ordinal form, such that regular ordinals led to a higher probability of correct comprehension. There was no significant main effect of ordinal: as the ordinal list progresses, the likelihood of a correct response decreases, but not significantly so. There was a significant main effect of age but the interactions were not found to be significant. However, there was a trend towards significance for the interaction between age and place in the ordinal list, such that the probability of a correct response tends to lower for the youngest CP-knowers as the count list increases (i.e., higher ordinals are more difficult for younger children).

5.2 Discussion
The outcome of the models aligns with the ideas put forward above. For one, children’s comprehension of ordinals is greater in CP-knowers than
in four-knowers (though we did not include the latter group in the model), and greater in older children. The main effect of (ir)regularity shows that regular ordinals are more likely to be understood correctly than irregular ones. (Both derde ‘third’ and achtste ‘eighth’ were coded as irregular here, though Figure 1 shows that only derde ‘third’ is actually problematic.) The lack of a significant effect of place in the ordinal list suggests children’s performance on all (regular) ordinals was more or less stable throughout the list, which is in line with the all-or-nothing type of performance associated with rule-based learning. We go into these points below.

In Chapter II, cardinal acquisition preceded ordinal acquisition, and cardinal knowledge predicted performance on ordinals. The data here are in line with this pattern: children needed to be at least four-knowers to provide correct responses on any ordinals, and two-knowers had to be excluded altogether. This makes sense given that children have to learn that numerals refer to discontinuous quantities (which happens in the three-knower stage, see Sarnecka 2015) and ordinals are inherently discrete. Children thus need to be in an advanced stage of cardinal acquisition before they can acquire ordinals.

The descriptive data strongly suggested children would perform equally on all ordinals, and this suggestion is reflected in the model as well: there was no significant main effect of place in the ordinal list. This is in line with the idea that ordinals are acquired by means of a rule: before the ordinal formation rule is in place, performance on all (regular) ordinals is relatively poor, but once the rule is acquired, all forms that follow the rule evoke better performance than those that do not. This is also clear from children’s performance on *driede ‘third’. This regularized yet ungrammatical form cannot have been encountered in the input, yet children scored as high on *driede as they did on regular (grammatical) ordinals. Something similar applies to *eende and *eenste, regular ordinal versions of eerste ‘first’. Though één ‘one’ should not be able to serve as a root for ordinal formation (see Barbiers 2007), children have no difficulty interpreting these forms. These findings support the idea that children are able to decompose ordinal forms and use their morphological structure to arrive at a sensible interpretation, which in turn makes the idea that children rely on purely lexically stored knowledge less likely and rule-based learning more so.

The sensitivity or the exact form of this rule, or more precisely: which suffix(es) children feed into their morphological machinery, cannot be determined on the basis of the comprehension data. If children had
massively failed to comprehend *achtste* ‘eighth’, that would have been clear
evidence that their rule only accepts –*de* as an ordinal suffix. However, the
data reveal no such major differences in performance between *achtste*
‘eighth’ and *negende* ‘ninth’, for example. This could mean that (i) some
lexical knowledge is involved, (ii) children recognize –*ste* as an allomorph
of –*de*, (iii) children do not find the difference in suffix to be salient or
problematic (sloppy “rule”). Performance on this irregular ordinal
therefore does not seem affected by its suffix or e.g., its token frequency
(though we did not include frequency explicitly in our model, given that
the frequency drops as the ordinal list progresses, and the ordinals we
tested did not provide us with a means to properly disentangle the two).
Despite the lack of a significant main effect of place in the ordinal list, we
believe (in line with Chapter II) that this might play a role, which may
become visible in a larger sample. Moreover, note that frequency or place
in the count list do not work against *derde* ‘third’, which evoked many
errors, despite being low in the count list and relatively frequent (*derde *
‘third’ is at least twice as frequent as *vierde* ‘fourth’ and four times more
frequent than *zesde* ‘sixth’, let alone *achtste* ‘eighth’).

Our results differ from what is described in Chapter II in that the
place in the ordinal list is not quite significant in our model, only as an
interaction effect with knower-level. Of course, the children in our sample
were somewhat older and more advanced in general, as we lacked children
in the lower subset-knower stages and our four-knowers and CP-knowers
performed better overall than the children reported in Chapter II. There
we attribute weaker performance on higher ordinal *achtste* to non-
linguistic factors. It might also be that the CP-knowers in our sample are
simply past the stage at which these extra-linguistic factors (e.g., not
losing count) are clearly visible. Children who perform at or near ceiling
provide the model with limited material to work with, leaving it difficult
to see whether an effect of ordinal might still be there, or has been there
before, and our four-knowers are so few in number that we could at best
speculate about what dictates the variation in their behavior, although the
sloped decrease in correct responses makes a performance-account likely.
It also raises the question what factor contributes to the ceiling
performance in CP-knowers here, that was not found in the previous
study. We leave this for future work to explore.

In summary, our data support the idea that children understand
cardinals before they can fully grasp ordinals, and that they acquire
ordinals in a rule-based fashion. We see that *derde* ‘third’ is more difficult
than regular ordinals such as *tweede ‘second’ and *vierde ‘fourth’ and ungrammatical yet regularized forms (*eende, *eenste, *driede) pose no problems. Note that while this must entail that children see ordinals as complex forms and are able to extract a relevant meaning from an ordinal’s parts (at least in the context of this task), the responses to *achtste ‘eighth’ do not provide additional evidence for a specific rule that children may be using. For this, we must turn to production.

6. Production
The following data are based on the same children who were discussed above; we excluded the same three subset-knowers that were also excluded from the comprehension analysis. We coded a child’s response as correct if both the root and the suffix matched the form used in adult Standard Dutch. Errors were then categorized into one of six different groups, according to the suffix produced (–de, –ste, –te, –e), the use of the corresponding cardinal (whether it was preceded by a determiner or not, e.g., (de) negen ‘(the) nine’ when the target was negende ‘ninth’). We combined some of the error categories for the *achtste ‘eighth’ items: devoiced realization of –de as –te, and even reduction to –e was considered the same (all as regularized *achtde), as the distinction was not always clearly audible. All remaining responses (or lack thereof) were coded as ‘other’.

6.1 Results
Figure 2 provides an overview of the percentage of correct responses per elicited ordinal per knower-group.

Figure 2: Percentage of correct responses. Error bars indicate 95% CI.
The figure shows that four-knowers only provide a correct response about half of the time for most ordinals. These children score worst on irregular ordinals, with zero correct responses for derde ‘third’ and just one correct response (6.6%) in response to achtste ‘eighth’. The CP-knowers do better generally, scoring comparably high on regular ordinals tweede ‘second’, vierde ‘fourth’ and zesde ‘sixth’ as on the comprehension test. Here, scores on tweede are significantly better than on vierde ($Z = -8.604, p < 0.001$) and erste ($Z = -2.625, p < 0.009$) but worse than zesde ($Z = -4.994, p < 0.001$). Irregular ordinals elicit fewer correct responses as well as, interestingly, negende ‘ninth’. Scores on achtste ‘eighth’ are significantly lower than on derde ($Z = -12.574, p < 0.001$) and negende ‘ninth’ (-3.690, $p < 0.001$), despite the relatively poor performance on negende ‘ninth’.

While the above provides some kind of insight in children’s performance, we would like a more fine-grained analysis of the factors that may influence adult-like behavior on this task. We therefore fit a generalized linear mixed-effects logistic regression model to determine the effect of different factors on the probability of a correct response, much in the same way as we did for our comprehension test, again focusing on CP-knowers only, leaving out superlatives and testing only the six true ordinals we tested. We included by-subject random intercepts with slopes for ordinal (place in the count list) as a continuous factor and by-trial random intercepts with slopes for age in months. We included as fixed factors ordinal, regularity (i.e., whether the ordinal numeral was regular, as for e.g., zesde ‘sixth’, or irregular, as in the case of derde ‘third’), and age in months, plus the interactions between age and regularity, and age and ordinal. In addition, we hypothesized that comprehension of a given ordinal might affect production of that ordinal, and thus included comprehension scores as well. The dependent variable was whether a child’s response was correct or incorrect. Continuous factors were centered; categorical factors were coded with explicit contrasts before analysis, and no additional outliers were removed. Table 4 describes the result of this model.
From the above, we can see that there are significant main effects for all fixed factors on the likelihood of a correct response, all in the expected directions. For one, the higher the ordinal is in the count list, the less likely it is that a child will provide a correct response. Moreover, regular ordinals are more likely to elicit a target-like response than irregular ones. Having provided a correct response to a given ordinal in the comprehension task increases the likelihood of a correct response on the production task, as does (to a lesser extent) being older. No significant interaction between age and regularity was found, though there was a significant effect between ordinal and age, such that performance on the lower ordinals is predicted to reach ceiling levels at a younger age than the higher ordinals, especially achtste ‘eighth’ and negende ‘ninth’. This can also be concluded from the descriptive data in Figure 2.

We then compared the model in Table 4 to one in which regularity was excluded and ordinal was a categorical (rather than continuous) variable. Though this type of model did not lead to an improvement in the comprehension data in the previous section, the production model including ordinality as a categorical factor did have a lower AIC than the one including a combination of ordinal as a continuous factor and regularity (920.05 compared to 948.57), and this improvement was significant ($\chi^2 = 40.521$, $df = 6$, $p < 0.0001$). Figure 3 plots the interaction between ordinal and age in this model; Table 5 summarizes the model.
Figure 3: Interaction Age in Months by Ordinal. Model was run on centered variables; plot reflects converted scales.

Table 5: Result summary for correct responses to ordinals for 2, 3, 4, 6, 8 and 9: β coefficient estimates, confidence intervals, standard errors, associated Wald’s z-score and significance level (p) for all predictors in the analysis. Formula: Correct ~ OrdinalCategorical*AgeInMonths + Comprehension Score + (1 + OrdinalContinuous | Subject) + (1+ AgeInMonths | Item).

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimate</th>
<th>CI</th>
<th>SE</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.418</td>
<td>0.897 – 1.940</td>
<td>0.266</td>
<td>5.332</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ordinal 234-689</td>
<td>-0.614</td>
<td>-3.821 – -3.805</td>
<td>1.127</td>
<td>-5.336</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ordinal 24-3</td>
<td>-2.534</td>
<td>-3.422 – -1.646</td>
<td>0.453</td>
<td>-5.593</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ordinal 2-4</td>
<td>-1.858</td>
<td>-2.962 – -0.754</td>
<td>0.563</td>
<td>-3.300</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ordinal 69-8</td>
<td>-1.926</td>
<td>-2.430 – -1.422</td>
<td>0.258</td>
<td>-7.492</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Ordinal 6-9</td>
<td>-3.479</td>
<td>-4.257 – -2.701</td>
<td>0.397</td>
<td>-8.762</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age</td>
<td>0.126</td>
<td>0.066 – 0.185</td>
<td>0.030</td>
<td>4.147</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Comprehension</td>
<td>2.130</td>
<td>1.861 – 3.399</td>
<td>0.648</td>
<td>3.29</td>
<td>0.0010</td>
</tr>
<tr>
<td>Ordinal 234-689</td>
<td>-0.453</td>
<td>-0.704 – -0.203</td>
<td>0.128</td>
<td>-3.545</td>
<td>0.0004</td>
</tr>
<tr>
<td>Ordinal 24-3</td>
<td>0.038</td>
<td>-0.065 – 0.140</td>
<td>0.052</td>
<td>0.715</td>
<td>0.4744</td>
</tr>
<tr>
<td>Ordinal 2-4</td>
<td>-0.084</td>
<td>-0.191 – -0.024</td>
<td>0.055</td>
<td>-1.528</td>
<td>0.1266</td>
</tr>
<tr>
<td>Ordinal 69-8</td>
<td>-0.096</td>
<td>-0.155 – -0.037</td>
<td>0.030</td>
<td>-3.21</td>
<td>0.0013</td>
</tr>
<tr>
<td>Ordinal 6-9</td>
<td>0.038</td>
<td>-0.050 – 0.127</td>
<td>0.045</td>
<td>0.849</td>
<td>0.3956</td>
</tr>
</tbody>
</table>
This model shows similar effects for comprehension scores and age: children who performed well on a given ordinal in the comprehension task are more likely to do well on that ordinal in the production task, and older children are more likely to succeed than younger ones. However, where this model differs is where it comes to the effect of ordinal. Contrasts in the model above were coded to isolate irregular *derde* ‘third’ and *achtste* ‘eighth’ and to mimic going through the count list. The results show that the higher half of the tested ordinals (*zesde*, *achtste* and *negende*, ‘sixth’, ‘eighth’ and ‘ninth’) are less likely to be produced correctly than the lower half. Within the lower ordinals, we can see that irregular *derde* ‘third’ is less likely to be produced correctly than its regular neighbors, and that the probability of a correct response is lower for *vierde* than *tweede* ‘second’. These observations are in line with the idea that morphology affects production, but also consistent with the assumption that higher ordinals are harder. A similar pattern is seen within the high ordinals: *achtste* ‘eighth’ leads to a lower probability of an adult-like response than its regular neighbors, outweighing the influence of the place in the count list itself, but that *negende* ‘ninth’ is also harder than *zesde* ‘sixth’.

Figure 3 helps to understand the interaction terms better. For *tweede* ‘second’ and *vierde* ‘fourth’ and irregular *derde* ‘third’ there are no real surpises, However, we can see that the distinction between low ordinals and higher ordinals is more complex. The predicted probability of a correct response is relatively high for *zesde* ‘sixth’, from very early on. For *achtste* ‘eighth’, which is both high and irregular, it remains low, whereas the predicted performance on *negende* ‘ninth’ increases over time. The fact that this model improves upon the former one suggests that the factors regularity and ordinal (continuous) in the previous model explain less of the variance when considered independently than when taken as a combined property within each individual ordinal. Figure 3 reflects that this indeed seems to be the case. This did not hold for our comprehension data, but as we suggested in section 3, children can be more lenient when it comes to interpreting ordinals in context. Production requires being precise. Moreover, other factors specific to each ordinal (e.g., phonological factors) may also play (more of) a role, as well as effects of different kinds of irregularity, which would also explain why a model considering ordinals individually yields a better result than one that does not.

We might also wonder what children’s incorrect responses look like, since rule-based learning typically goes hand in hand with one particular kind of error: overgeneralizations. Though most children provide too few
errors to say anything about the consistency within their errors, Figure 4 shows the distribution of answers for each of the tested ordinals for both knower-level groups. Percentages reflect the percentage of a given response type overall.

Figure 4 shows that while the distribution of response types differs somewhat between each ordinal for each knower-level, some general tendencies are also clear. For example, when a four-knower provides an incorrect response, chances are the child will produce the corresponding cardinal numeral in the place of the ordinal, whereas CP-knowers who make errors tend to overuse the suffix –ste, i.e., say *negenste rather than negende ‘ninth’. 10 Negende is also the ordinal where this answer type

Produced form: ■ –de  □ –ste  ▪ –te  △ –e  ▪ Cardinal  □ Other  □ *driede

Figure 4: Distribution of responses per target ordinal per knower-level.

10 Many of these cardinal forms were not adult-like analytic ordinals. For example, sometimes a determiner was used (*de drie), and cases such as auto (nummer) drie ‘car (number) three’ hardly ever occurred. These might be considered a type of conversion; conversion has been thought to be easier than derivation in acquisition (Clark 2014). More important, however, is the observation that responses such as (de) auto (nummer) drie ‘(the) car (number) three’ are relatively rare. Colomé & Noël (2012) hypothesized that French-speaking children might prefer such analytic ordinals, but neither they nor we find clear support for this idea.
occurs most often, and the only regular ordinal where production and comprehension scores do not align (of the responses from children with perfect comprehension scores on negende, 58.05% were incorrect; this percentage is under 20% for the other three regular ordinals). Note that the –ste bars on achtste ‘eighth’ represent correct responses, not errors, which also makes it immediately obvious that –de is the preferred form there. Most children provided consistent responses to the achtste ‘eighth’ trials: 55.39% never produced the correct form, while 18.46% always did.

Perhaps the most striking response pattern is found for derde ‘third’. None of the four-knowers produced derde on the appropriate trials; CP-knowers did so roughly half the time. The vast majority of errors were overgeneralizations of the cardinal root: *driede (striped bars), or *drieste, rather than derde (solid black bar). Overgeneralizations of –ste with the appropriate root allomorph (i.e., *derste) were not attested. Note that we expected that children who could not comprehend derde ‘third’ would also not produce it correctly. Only three of the correctly produced utterances on derde came from children who failed to find the third on all of the comprehension items, as opposed to 57 incorrect responses within the same group, and the child with one correct response on the comprehension task did not produce derde correctly once. Moreover, children who are able to find the third card on (nearly) all the comprehension trials, sometimes still struggle with production: within the group of children who had perfect comprehension scores, 27% of the production trials were incorrect.

The response patterns above differ considerably for erste ‘first’, as Table 6 shows. As with comprehension, children typically provided correct responses.

Table 6: Distribution of elicited responses to erste ‘first’ per knower-level.

<table>
<thead>
<tr>
<th>4-knowers</th>
<th>CP-knowers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Correct</strong></td>
<td><strong>Number</strong></td>
</tr>
<tr>
<td>Correct</td>
<td>7</td>
</tr>
<tr>
<td>*Eende</td>
<td>0</td>
</tr>
<tr>
<td>*Eenste</td>
<td>1</td>
</tr>
<tr>
<td>Een(e)</td>
<td>2</td>
</tr>
<tr>
<td>Voorste</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15</td>
</tr>
</tbody>
</table>
As a result, only rarely did we see e.g., *eende or *eenste, or use of één ‘one’ instead of eerste. Both suffixes occur, though –ste is slightly more common. In addition, some children produced a perfectly grammatical alternative superlative form: voorste ‘lit: frontmost’.

When taken together, we see overuse of both suffixes (i.e., –de in the case of achtste ‘eighth’ and occurrences of –ste elsewhere, especially on negen ‘nine’: *negenste). Sometimes the suffix is absent altogether and just the cardinal (or a cardinal with a determiner) is produced. These patterns also occur in response to derde ‘third’ stimuli, where we see children adding one of those suffixes to drie to arrive at an ordinal for three (*driede, *drieste), rather than using the irregular yet grammatical form derde ‘third’. (The form *derste does not occur.) Using één as a cardinal base to produce a regularized ordinal for first competes with an alternative in the superlative domain.

6.2 Discussion
The results on the Tell Me production task align with the idea that morphological structure plays an important role in producing ordinals correctly. Put in general terms, our reasoning was that children take in forms from the input, discover that they can decompose them to disentangle their meaning, after which they are able to use an ordinal formation rule to produce regular ordinals in the appropriate contexts as well. Irregular ordinals, which do not transparently follow the rule, have to be learned separately and thus follow later (i.e., after acquisition of the rule).

Section 3 commented on the role of age, place in the count list and comprehension scores. Our mixed-effects models revealed the expected main effects of age, place in the ordinal count list, and comprehension scores. Age also significantly interacted with ordinal in both versions we ran. This suggest that while children undeniably improve with age (after all, they all become adultlike speakers), this process is not the same for all ordinals. While they are predicted to reach ceiling levels on regular ordinals (but negende) early on, the others lag behind.

This is not surprising in general terms. Following a rule-based line of reasoning, one would expect that regular ordinal production comes in around the same time as the child discovers the rule, or slightly thereafter. For irregular forms, we expect production to follow comprehension of the rule (though not necessarily of the corresponding item in comprehension).
Children who actively use a rule to produce ordinals, are likely to overgeneralize this rule to the irregular instances (derde ‘third’ and achtste ‘eighth’). This is what we found: not only did production generally lag behind comprehension, this was especially true for the two irregular forms derde ‘third’ and achtste ‘eighth’. The problem appeared to be more persistent in the latter case, as more errors occurred on achtste–trials than on those targeting derde and the model suggests that performance on derde ‘third’ becomes targetlike before performance on achtste is. This may suggest that root allomorphy is easier to overcome than the alternative suffix on achtste (for saliency or frequency reasons), but we cannot rule out that place in the ordinal count list (see also Table 5) also plays a role. After all, performance on negende ‘ninth’ was low, though the model predicts performance on negende eventually passes achtstse. Counting up to the higher ordinal is conceivably more taxing, which may mean the added burden of the exception is too much for some children. However, that raises questions about the relatively high proportion of correct responses to zesde ‘sixth’ trials, especially compared to the lower regular ordinals. We believe the way we coded the responses may have affected the outcome here, as the distinction between –ste and –de could not be made here, reducing the odds of an incorrect response.

The production errors elsewhere, however, provide stronger evidence against the performance account and in favor of the idea that children make use of a rule quite generally. For one, the regularized yet ungrammatical form *driede ‘threeth’ is preferred over derde ‘third’. The widespread occurrence of this *driede shows that children are actively using some sort of rule during the production task, as this form is ungrammatical and therefore not in the input. We also find overgeneralizations of –de on achtste (*achtde) and to a lesser extent –ste on other ordinals (*tweeste, *negenste). This means that children consider these suffixes as alternatives for one another: they both make ordinals when added to a cardinal. The question is why some children would prefer one form over the other. Overuse of –de is the most frequent but perhaps not so exciting; if the input provides mostly evidence from ordinals under twintigste ‘twentieth’, then children have much more evidence for –de than for –ste, and so the overgeneralization is clearly input-driven. For those few children who systematically prefer –ste, we would have to say they must be considering evidence from higher ordinals (over twintigste ‘twentieth’) for the ordinal rule, to the extent that –ste receives default or elsewhere status and –de is considered an exception or more specific
instance. (See e.g., Yang 2017 for an account of how input, and how much input, is needed to account for rules and the exceptions to these rules.) We would not want to assume the –ste is overgeneralized from the –ste on eerste ‘first’, laatste ‘last’ and other superlatives, as it is unclear what the underlying semantics of such ordinals would be and what the exact analysis of such a form would be (i.e., whether cardinals must be seen as adjectives).

The question remains why *negenste is such a frequent error, if most children produce *achtde ‘eighth’ and hardly any children systematically overgeneralize –ste to all ordinals. Individual response patterns suggest there might be a neighboring effect: of the 21 children who produced negenste at least twice (out of three trials), only three always produced *achtde; 11 always produced achtsste correctly and the others produced a mix. Put differently: once the child switches suffix, he or she might switch to that suffix for the next ordinals. This is also consistent with one of the patterns attested in dialects of Dutch (Sleeman 2017). Of course, further investigation is needed to see if children maintain –ste through higher ordinals consistently.

Overregularizations are much less common when it comes to eerste ‘first’: most children produce this form correctly, meaning forms such as *eende and *eenste are nearly non-existent in production. One possible explanation for the lack of errors could be that eerste ‘first’ is so frequent that it holds a clear and established position in the child’s lexicon, and that this form blocks or prevents overregularizations of the *eende type (similar to the way went blocks *goed or best blocks *goodest; cf. Embick & Marantz 2008 for theoretical and comparative discussion of blocking in DM and other approaches). However, if some sort of blocking were a likely explanation, then we would also expect other alternatives to eerste to be blocked, yet many children who can find the eerste in the comprehension task produce voorste ‘frontmost’ in the production task. Note, moreover, that voorste and eerste are both perfectly grammatical superlatives, making voorste also a closer alternative to eerste than the ordinals *eende and *eenste. This suggests that children may already have fairly precise knowledge of other ordinal properties. As Barbiers (2007) argues, een ‘one’ lacks the feature composition required for ordinal formation; if children have this feature specification in place, that would mean *eende is not coincidentally absent, but inherently impossible. These regularized forms are therefore not suitable alternatives to eerste ‘first’ in the context of the task, but the superlative voorste ‘frontmost’ is a syntactically and
semantically viable option. Further research would be needed to investigate children’s knowledge of ordinal features, and what leads some children to prefer *voorste* over *eerste*.

Our production data together support the idea that ordinals are acquired in a rule-based fashion. We see that comprehension precedes production, and that regular ordinals are nearly all produced properly at around the same time, and that overgeneralization errors all point in the direction of the application of a rule. For most children, that rule means attaching a suffix –*de* to a cardinal base. In a small group, suffix –*ste* is overgenerated across the board.

7. Conclusion
The goal of this study was to investigate whether Dutch children acquire ordinals in a rule-based fashion, and whether there are other factors (numeric-conceptual difficulties, frequency, extra-linguistic factors) that play a role in this process. Unlike previous work, which focusses on comprehension only, our perspective is comparative: we discuss data from a comprehension task and a production task we administered to 68 typically-developing monolingual Dutch children between the ages of 3;3 and 6;0. The results are in line with the findings and the proposed acquisition path presented in Chapter II: cardinal knowledge and ordinal rules rule, age, token frequency and other factors are less important than morphological transparency.

The comprehension test supported the earlier (intuitive) finding that substantial cardinal knowledge is in place before ordinals are acquired: the two-knowers in our study were not able to identify ordinals correctly at all, four-knowers performed worse than CP-knowers and performance on ordinals was generally worse than on cardinals. The first step towards understanding ordinals seems to begin with the superlative *eerste* ‘first’, quickly followed by the regular ordinals e.g., *tweede* ‘second, lit: twoth’ and *vierde* ‘fourth’. The effect of the place in the ordinal count list seems to matter less than in Chapter II, as no main effect of ordinal was found here and only four-knowers did worse on higher ordinals than lower ones. (This is unsurprising, given that four-knowers by definition only understand low cardinals as well.) Moreover, performance was worst on the irregular ordinal *derde* ‘third’, suggesting that the form of the ordinal influences acquisition. The effect of irregularity was visible on *achtste* ‘eighth’, for four-knowers only.
That the form is important is further supported by the comprehension data we collected for the regularized yet ungrammatical form *driede ‘three–th’, and even *eende ‘one–th’ and *eenste ‘one–st’. These forms are absent from the input, yet children have no difficulty discerning what they must mean. In fact, performance on *driede was even better than on its grammatical counterpart. This suggests they are decomposing these forms on the spot, actively applying a rule to reach an appropriate interpretation.

The production data also support productive use of an ordinal formation rule: where adults would produce derde and achtsste, children often respond with *driede and *achtde, overgeneralizing the rule in both cases. In *driede the root allomorphy is not realized, and in *achtde the suffix for ordinals under twenty is used. Interestingly, the issues with achtsste ‘eight’ are more persistent than those with derde ‘third’, whereas the opposite holds for comprehension: there, derde ‘third’ is more difficult than achtsste ‘eighth’. This suggests that irregularities in the suffix are less salient than those in the root, making them easier to ‘ignore’ but also harder to produce correctly. This also makes occurrences of *negenste somewhat confusing, though while it is unclear what they mean for children’s ordinal rule, they at least argue against basic lexical learning, as this form does not occur in the input.

There are three points worth noting for future study. The smallest of these is the observed preference in some children for the form *negenste instead of negende ‘ninth’. The reason for this error is unclear, as is how persistent it is over time and across the count list. The second point pertains to eerste ‘first’, which is equally unproblematic in production as it is in comprehension. However, the fact that *eende and *eenste are sometimes produced raises questions for children’s analysis of these forms, which should be impossible under Barbier’s (2007) analysis.

Finally, the most obvious route for future research is to investigate the acquisition of relatively irregular count lists (such as English). Would, despite the many exceptions at the very beginning of the ordinal list, a rule-based approach (computation) still be more economical than lexically acquiring ordinals in the same one-by-one fashion cardinals are acquired (storage)? Of course, this would have implications for how children treat the input before having acquired such ordinals. For now, however, we conclude that at least Dutch-speaking children acquire ordinals in a rule-based fashion, and leave learners of other languages for future study.
Chapter IV

Comparing Dutch and English*

1. Introduction

Acquiring a language for the first time is no small feat. Children are somehow able to break down the endless stream of sounds they hear into smaller bits and pieces that fit into an intricate system of meaning and structure. How do they do it? This paper does not aspire to answer that question in its broadest sense, but does provide evidence that linguistic structure can be a useful and perhaps necessary tool in acquiring meaning and developing abstract concepts, even when the evidence in the input does not seem immediately obvious. More precisely, we argue that children use the morphosyntactic properties of ordinal numerals to acquire ordinal meaning, and that this strategy is not as straightforward as it might seem.

Our argument builds on the idea in Chapters II and III that irregular ordinals, such as derde ‘third’, take more time to be fully acquired than regular ordinals such as vierde ‘fourth’ or zesde ‘sixth’. Moreover, they note that regular ordinals all seem to be acquired at (roughly) the same time, which is sometime after children acquire at least the first four cardinals but usually after children have become fully competent counters (cardinal principle knowers, or CP-knowers). Because of this, the authors reason that children acquire these ordinals via a rule, deriving the meaning of the complex whole from its parts: the cardinal root and the ordinal suffix.

Intuitively, this approach could be plausible for Dutch, as there are very few irregular ordinals to begin with: following the definition in Chapter II only derde ‘third’; in Chapter III and the present paper only derde ‘third’ and achtste ‘eighth’. This means that the evidence for the ordinal formation rule (informally: cardinal plus –de on low ordinals or –ste on twintig ‘twenty’ and higher) is quite robust. One wonders, however, whether this rule-based approach would still be worthwhile for learners of a less regular ordinal count list, such as English: the first five forms in the

* This chapter was adapted slightly from Meyer, Caitlin, Fred Weerman & Sjef Barbiers (submitted). Many systems, one strategy: acquiring ordinals in Dutch and English.
English ordinal list do not even hint at a rule or underlying structure, regardless of your definition of (ir)regular, and precisely these low ordinals are likely to be the most frequent in the input.¹ This raises the question whether children would first acquire the lower ordinals lexically and acquire higher ordinals (lexically or via a rule) later on, or whether they would ‘wait’ and acquire the regular forms first, and the irregular forms lexically afterwards. It also raises questions about the relationship between ordinal forms and ordinality: do children grasp (exact, numerical) ordinality along with a given ordinal form, or does perhaps a more transparent but less frequent form such as car (number) three also suffice?

If English learners were to acquire ordinals lexically, then obviously an ordinal formation rule is not necessary for acquisition, but it would not exclude the possibility that Dutch children do make use of a rule. A different approach to ordinals in these languages, would, however, lead to questions about where the threshold for rule-based learning is: how many exceptions can a learner tolerate before resorting to lexical learning (cf. Yang 2016), i.e., storing the ordinals one by one as wholes (rather than productively deriving them as complex forms)? On the other hand, if English learners exhibit a learning pattern more consistent with rule-based learning, this would support the account in Chapters II and III, but would still be a remarkable finding: not only is such a pattern atypical of acquisition patterns found for derivational morphology (which generally follows a lexical pattern initially, and is acquired relatively late, cf. Clark 2014), and inflectional morphology (which typically exhibits a u-shaped or “change for the worse” pattern, e.g., Marcus, Pinker, Ullman, Hollander, Rosen & Xu 1992; Pinker 1999 and cf. discussion in Chapter III), but it also deviates from the slow and stepwise pattern found for cardinal acquisition (e.g., Condry & Spelke 2008; Le Corre and Carey 2007; Le Corre, Van de Walle, Brannon & Carey. 2006; Negen & Sarnecka 2012; Wynn 1992 among many others).

This paper first briefly summarizes work on the development of cardinal and ordinal numerals, and raises two questions pertaining to the acquisition of ordinals: (i) to what extent does the acquisition of ordinality rely on a particular form, and (ii) to what extent is the ordinal acquisition

¹ Obviously, not all of these forms are irregular in the same way, with second being a clear case of suppletion, for example, while in fifth the ordinal affix is still accessible and the irregularity is restricted to (phonologically conditioned) root allomorphy. Here we take irregular ordinals to be any synthetic ordinal that does not immediately follow from adding –de (for Dutch) or –th (for English) to a cardinal base.
pattern language-specific? This leads us to compare different ordinal types in Dutch and English. We describe these ordinal systems in section 3, highlighting their similarities and their differences. This brings us to our hypotheses and predictions (section 4), which we test for both languages in sections 5 and 6. The results of both tests lead us to conclude that while English and Dutch have considerably different ordinal systems, children acquiring these systems use the same strategy: they use language (i.e., a morphological rule) to apply abstract numerical knowledge they developed in cardinal acquisition to the ordinal domain.

2. Numerals in acquisition
If the claim is that children use knowledge from the cardinal domain in the ordinal domain, then we need to understand how that cardinal knowledge develops before we can compare these processes. Three decades of experimental work on cardinal acquisition consistently shows that children are slow to acquire the exact meanings of cardinals and master verbal counting (e.g., Condry & Spelke 2008; Le Corre and Carey 2007; Le Corre et al. 2006; Negen & Sarnecka 2012; Wynn 1992). These studies describe a tiered developmental trajectory in which children acquire the exact meanings of the first four cardinals one by one, progressing through a series of so-called ‘knower-levels’. During these initial stages (as pre-knowers, one-knowers, two-knowers, three-knowers and four-knowers), children only have an exact understanding of cardinals up to and including the highest cardinal in that stage, while all higher numerals denote only ‘more’ than the highest cardinal they know. Because these children only know a subset of the cardinals they can recite in their count list, they are collectively referred to as ‘subset-knowers’ (Le Corre et al. 2006).

By contrast, children in the final stage of cardinal acquisition, CP-knowers (or cardinal principle knowers), are fully competent counters who are able to infer the meanings of all the remaining cardinals in their count list, thereby making the counting routine productive. These children know that to answer the question how many, they are to apply at least three counting principles (see also Gelman & Gallistel 1978): the one-to-one correspondence principle (every cardinal belongs to one counted item), the stable order principle (the count list has a strict order), and the cardinal principle (the numerosity of the set is equal to the last number counted). Children may reach this stage by the age of three, though many children are well into their fours when they make this conceptual leap (e.g., Huang, Spelke & Snedeker 2010; Le Corre & Carey 2007).
Despite considerable variation with respect to the start and duration of each stage, the process itself is quite robust: all studies show that children, irrespective of their cultural and linguistic background, follow the same slow and sequential pattern (e.g., Almoammer, Sullivan, Donlan, Marušić, Žaucer, O’Donnell & Barner 2013; Barner, Libenson, Cheung & Takasaki 2009; Condry & Spelke 2008; Huang et al. 2010; Le Corre & Carey 2007; Le Corre, Li, Huang, Jia & Carey 2016; Piantadosi, Jara-Ettinger & Gibson 2014; Sarnecka 2015; Sarnecka, Kamenskaya, Yamana, Ogura & Tudovina 2007; Wynn 1992 and Chapter II). The step from subset-knower to CP-knower has been linked to two innate, non-linguistic, cognitive systems that can be used to represent numerical concepts: the Object Tracking System (OTS), which allows for precise representations of sets of up to three or four individual items, and the Approximate Number System (ANS), which allows for inexact, ratio-sensitive representations of larger quantities. In order to overcome the limitations of each system and achieve precise representations of quantities over four, these two systems need to be combined (e.g., Le Corre & Carey 2007). We refer the reader to Sarnecka (2015) for a recent and more detailed overview of children’s development of numerical knowledge.

Much less robust evidence is available for ordinal acquisition, but the work that has been done collectively suggests that the procedure there is quite different from the cardinal one, despite the conceptual knowledge required for both numeral types being nearly identical. The only difference is that the counting procedure answers a different question: not how many, but which one, and so the cardinality principle is exchanged for the ordinality principle. The last count now represents the ordinality of the last item, rather than the cardinality of all items counted. Given these similarities, one might speculate (as do Meyer et al. 2016) that acquiring ordinals should be no different, or at least no more difficult, than acquiring cardinals. After all, what is conceptually more complex about picking out an individual from a set (ordinality) than representing the entire set (cardinality)?

The answer is practically irrelevant, because the facts point in a different direction: direct and indirect evidence suggests that children acquire cardinals before acquiring the corresponding ordinals. Pretest data in Matthei (1982) and Hamburger & Crain (1984) show that many children of CP-knower age fail to understand ordinals such as second and third: 15% of children aged three to six (M = 5;01) in the former study, and 24% of four-year-olds (4;05–5;09, M = 4;11) in the latter. More direct
evidence comes from Miller, Major, Shu & Zhang (2000), who show that children can count higher using cardinals than ordinals, and from Fischer & Beckey (1990), Colomé & Noël (2012) and the studies in this dissertation, who saw higher scores on cardinal comprehension conditions than ordinal ones.

Ordinal acquisition is not only later than cardinal acquisition, it also follows a different pattern. By comparing studies from four languages (Fischer & Beckey 1990 for English, Miller et al. 2000 for Chinese, Colomé & Noël 2012 for French and Trabandt, Thiel, Sanfelici & Schulz 2015 for German) we may conclude that the acquisition pattern is language-specific: learners acquiring a regular ordinal system such as Chinese do so at an earlier age than learners of English, which has a highly irregular count list (Miller et al. 2000). Though they report that American six-year-olds still struggle with ordinals 34% of the time, note that this is a mean score: 17 out 31 children obtained a perfect score, meaning that a little less than half must have performed well below chance. This suggests that ordinals (at least in English) are acquired quite abruptly, rather than incrementally.

This idea finds support in the studies discussed in the previous chapters, which provide cleaner and more robust evidence that (ir)regularity affects both the timing and pattern of ordinal acquisition in Dutch. They present data from two ‘Give Me’ type comprehension tasks (Wynn 1992, Colomé & Noël 2012) and a ‘Tell Me’ production task (Colomé & Noël 2012) that show that exceptions to the ordinal formation rule are acquired after forms that do follow the rule. In production, children make fewer errors on regular forms such as twee–de ‘second, lit: two–th’ and vier–de ‘fourth’ than on irregular der–de ‘third’ and acht–ste ‘eighth’ (which takes the suffix typically found on higher ordinals in Dutch). In comprehension, the difficulty with achtste ‘eighth’ is less clear, but derde ‘third’ is clearly problematic. Moreover, children are much better at comprehending the ungrammatical but regularized counterpart of derde, namely *driede ‘threeth’, which is also found in children’s (elicited and spontaneous) production. Similarly, children make overgeneralization errors on achtste, producing *achtde instead.2

2 They also found some instances of –ste overgeneration, namely negen–de ‘ninth’ produced as negen–ste, but they consider this to be an effect of the numeral’s proximity to achtste ‘eighth’. A reviewer of the present paper wondered whether the difficulty in comprehension or production is due to achtste containing an unusual consonant cluster, but note that the pronunciation of this ordinal in Standard Dutch is [uxtsta], which is
There we argue that this not only shows that the stepwise pattern found for cardinals (in which knowing a given numeral entails knowing all preceding numerals) does not hold for ordinals, but that children actually use ordinal morphosyntax to acquire ordinal meaning, i.e., ordinals are acquired in a rule-based fashion, at least in Dutch. They discern a number of developmental stages, given in (1). These stages hold for both comprehension and production, though the data in Chapter III suggest that the irregularity in derde ‘third’ plays a larger role in comprehension than production, whereas the opposite holds for the irregularity in achtste ‘eighth’.

(1) Stages in ordinal acquisition (taken from Chapter III):

(i) Children use morphosyntactic cues (such as the fact that ordinals combine with singular nouns whereas most cardinals combine with plurals) to discover that ordinals refer to individuals, not sets.

(ii) Children, when they are at least four-knowers, acquire eerste ‘first’ first. This form is acquired relatively early for three reasons. It does not require true counting competence, it is roughly 50% more frequent than tweede ‘second’ through twintigste ‘twentieth’ combined, and it has been shown to be a regular superlative (rather than an ordinal) in Dutch (Barbiers 2007).

(iii) Shortly thereafter, children acquire the ordinal formation rule (informally: cardinal + suffix = ordinal). Children in this stage comprehend at least low, regular ordinals such as tweede ‘second’, lit: two–th’ and vierde ‘fourth’.

(iv) Extra-linguistic factors influence performance on higher, regular ordinals: the further one has to count and maintain one-to-one correspondence, the more demanding the task becomes. Knowledge of higher ordinals is by definition limited to CP-knowers only, since children who cannot count beyond four cannot be expected to count to higher ordinals either.

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simpler than orthography suggests. This combination of consonants is also found elsewhere, such as in zachtste ‘softest’ [zɑxtstə]. The [t] in the root is often elided in these cases, which may affect transparency, but the phonological complexity is comparable to ordinals formed with –tig [tix] (e.g., twintigste ‘twentieth’).
Performance on irregular forms (derde ‘third’ in comprehension and production, and achtste ‘eighth’ in production) improves after acquisition of the rule. Note that this might be before or after performance on higher ordinals improves.

The stages show that while cardinal knowledge and age play a role, as does the place in the ordinal count list, the most influential factor in this process is the ordinal form itself. To explain the developmental pattern in (1), the claim is that ordinals are acquired “from the inside out” rather than “from the outside in”: children arrive at a correct interpretation of an ordinal by actively treating it as a complex form, i.e., deriving the meaning of the whole from its parts, rather than lexically acquiring a number of ordinals as simplex forms that are then later seen as complex, i.e., the product of a productive rule. In other words, the claim is that children recognize that the ordinal vierde ‘fourth’ consists of a cardinal root four and a suffix –th, and hence must differ in meaning from the cardinal alone. After applying the relevant counting principles to the cardinal root, they can then add on the semantic contribution of the ordinal suffix (which is to denote an individual rather than the cardinality of a set) and arrive at the appropriate interpretation of the whole. This approach works for both comprehension and production, but only for regular ordinals. Root allomorphy can be confusing: some children, when asked to find de derde ‘the third’, claim er is geen der ‘there is no der’, or produce *driede ‘threeth’ when asked to name the third place in line. This suggests they recognize the ordinal structure, consisting of an ordinal suffix and a cardinal root, and attempt to apply the rule, but fail in identifying the allomorph as such. The rule comes first, and exceptions are acquired lexically later on. The claim here is that ordinals are productive in adults and children; how they are ultimately processed or represented is a topic for future study. While each simplex cardinal possesses its own lexical entry in the Mental Lexicon, complex cardinals and ordinals (both regular and irregular) could be processed via morphological decomposition in addition to being stored.

A rule-based approach to acquisition seems reasonable enough, given the data in Chapters II and III: why else would children have difficulty with irregular forms while mastering regular ones, even regular ordinals that are dramatically less frequent and further down the count list? Dutch ordinals also provide fairly consistent evidence for an ordinal formation rule. However, if we look at different areas of language acquisition, the literature would lead us to expect ordinal numerals to be
a product of storage (lexical learning), rather than computation (rule-based learning). Ordinals are a case of derivation, and the limited work describing derivational morphology in child language suggests that while derived forms may appear quite early, it takes time for children to use most affixes productively (leaving aside cases of conversion/zero derivation, which are easier). Clark (2014) notes that children learn individual (complex) forms lexically at first, and need to collect sufficient evidence for their morphological complexity in order to generalize over these examples and form a productive rule. She points out that this process is affected by the productivity of the rule, as well as by the identifiability and transparency of both the root and the affix.

Two questions now arise. The first is whether the specific ordinal form is critical in grasping ordinal meaning or whether difficulties in comprehension can be avoided by using a different structure altogether. Of course, the opacity in derde ‘third’ has been shown to be resolvable via overgeneralization (i.e., *driede ‘threeth’), but perhaps a syntactically derived (analytic) ordinal such as hoofdstuk (nummer) drie ‘chapter (number) three’ also suffices (cf. discussion in Chapter III). While such forms are intuitively much less frequent, and have a different semantic flavor, the underlying cardinal base is completely transparent. Comparing such forms to (ir)regular synthetic ordinals such as derde ‘third’ and vierde ‘fourth’ may be a way to approach the relationship between the transparency, form, and frequency of ordinals in acquisition. We return to this in section 3.

The second question is how language-specific the pattern is. The limited ordinal acquisition studies mostly focus on languages with an ordinal system more regular than the Dutch one (i.e., Chinese, French, and German, cf. Miller et al. 2000; Colomé & Noël 2012; Trabandt et al. 2015), but the appeal of the rule might decrease in less transparent systems. The existing literature provides us with no means to tell. While Miller et al. 2000 show that English ordinals are acquired later than Chinese ones, and Fischer & Beckey (1990) suggest that third is more difficult than fifth, there is no study (to our knowledge) that directly and precisely investigates the age and order of acquisition of ordinals within a more irregular ordinal system (such as the English one) and/or compares the acquisition of ordinals between a (relatively) regular ordinal system (such as Dutch) and an irregular one (such as English). The goal of this study is to do just this: we extend the work carried out for Dutch, and compare these results to a similar task set up for English.
3. Ordinals in Dutch and English

Dutch and English have considerably different ordinal count lists. Putting aside *eerste* ‘first’ (a superlative, cf. Barbiers 2007), Dutch has one irregular ordinal, morphophonologically irregular *derde* ‘third’, and two ordinal suffixes: –*de* (used for nearly all of the first nineteen ordinals) and –*ste* (for higher ordinals and *achtste* ‘eighth’). English only has one ordinal suffix, namely –*th*, but English learners are confronted with a different challenge: reliable evidence for the English ordinal rule only appears from *sixth* on, and the irregularities are all of a different nature (e.g., suppletion, vowel reduction, metathesis). The actual mechanism of the rule is otherwise the same, as the suffix attaches to the rightmost part of the cardinal base, and the ordinal meaning takes scope over the entire numeral.

Table 1 provides an overview of the first twenty cardinals and ordinals in Dutch, including their frequencies in the *Corpus Gesproken Nederlands* ‘Spoken Dutch Corpus’ (Oostdijk 2000), and the frequency data for the first twenty ordinals in English, taken from the spoken section of COCA (Corpus of Contemporary American English (Davies 2008)). The CGN data were taken from Chapter II. The COCA data were found by searching for each of the individual ordinals tagged as such. The CGN contains approximately 9 million words in 1000 hours of speech files from the Netherlands and Flanders; COCA has nearly 110 million words taken from transcripts of over 150 television and radio programs. The absolute frequencies for both languages represent the frequency per million words and the relative frequencies represent the proportion of occurrences of each ordinal relative to all ordinals tallied in the table for that language. Put differently, out of every million words in Dutch as tallied in the CGN, roughly 2061 are ordinals between *eerste* ‘first’ and *twintigste* ‘twentieth’, and of these ordinals, some 387 of them (18.79%) are *tweede* ‘second’.

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3 Frequencies in child-directed speech in CHILDES are too low to provide meaningful insight in ordinal use, other than that the evidence for them as a group is scarce.
Table 1: Absolute (per million words) and relative frequencies of the first twenty ordinals in Dutch and English. Data taken from the CGN (Oostdijk 2000) and COCA (Davies 2008).

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>één</td>
<td>eer–ste</td>
<td>1214.11</td>
<td>58.90%</td>
<td>1260.40</td>
<td>71.45%</td>
</tr>
<tr>
<td>2</td>
<td>twee</td>
<td>tweede</td>
<td>387.33</td>
<td>18.79%</td>
<td>287.89</td>
<td>16.32%</td>
</tr>
<tr>
<td>3</td>
<td>drie</td>
<td>der–de</td>
<td>151.44</td>
<td>7.35%</td>
<td>111.82</td>
<td>6.34%</td>
</tr>
<tr>
<td>4</td>
<td>vier</td>
<td>vier–de</td>
<td>69.89</td>
<td>3.39%</td>
<td>36.55</td>
<td>2.07%</td>
</tr>
<tr>
<td>5</td>
<td>vijf</td>
<td>vijf–de</td>
<td>40.22</td>
<td>1.95%</td>
<td>23.27</td>
<td>1.32%</td>
</tr>
<tr>
<td>6</td>
<td>zes</td>
<td>zes–de</td>
<td>37</td>
<td>1.79%</td>
<td>12.22</td>
<td>0.69%</td>
</tr>
<tr>
<td>7</td>
<td>zeven</td>
<td>zeven–de</td>
<td>17</td>
<td>0.82%</td>
<td>8.71</td>
<td>0.49%</td>
</tr>
<tr>
<td>8</td>
<td>acht</td>
<td>acht–ste</td>
<td>10.78</td>
<td>0.52%</td>
<td>7.83</td>
<td>0.44%</td>
</tr>
<tr>
<td>9</td>
<td>negen</td>
<td>negen–de</td>
<td>9.67</td>
<td>0.47%</td>
<td>7.96</td>
<td>0.45%</td>
</tr>
<tr>
<td>10</td>
<td>tien</td>
<td>tien–de</td>
<td>17.89</td>
<td>0.87%</td>
<td>3.23</td>
<td>0.18%</td>
</tr>
<tr>
<td>11</td>
<td>elf</td>
<td>elf–de</td>
<td>7.78</td>
<td>0.38%</td>
<td>0.68</td>
<td>0.04%</td>
</tr>
<tr>
<td>12</td>
<td>twaalf</td>
<td>twaalf–de</td>
<td>9.67</td>
<td>0.47%</td>
<td>0.57</td>
<td>0.03%</td>
</tr>
<tr>
<td>13</td>
<td>der–tien</td>
<td>der–tien–de</td>
<td>8.22</td>
<td>0.40%</td>
<td>0.35</td>
<td>0.02%</td>
</tr>
<tr>
<td>14–19</td>
<td><em>cardinal</em></td>
<td><em>cardinal</em>–de</td>
<td>65.78</td>
<td>3.19%</td>
<td>1.75</td>
<td>0.10%</td>
</tr>
<tr>
<td>20</td>
<td>twintig</td>
<td>twintig–ste</td>
<td>14.67</td>
<td>0.71%</td>
<td>0.85</td>
<td>0.05%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2061.44</strong></td>
<td><strong>Total</strong></td>
<td><strong>1764.08</strong></td>
<td><strong>100%</strong></td>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Table 1 shows that both Dutch and English exhibit a similar frequency pattern, in which *eerste* and *first* are by far the most frequent, with *tweede* and *second* trailing behind and all other frequencies quickly dropping to extremely marginal levels.\(^4\) Note that we follow Barbiers (2007) and

\(^4\) The patterns in Dutch and English are similar, but not the same: there is somewhat more variation in Dutch and the higher ordinals are less infrequent than in English (though cf. Dehaene & Mehler 1992). In fact, ordinals *sixth* through *twentieth* together only count for 2.49% of the attested ordinals, whereas Dutch *zesde* through *twintigste* count for 11.57%. Possible reasons for such differences may include war references for *eerste* and *tweede* (*de tweede wereldoorlog* ‘the second world war’ is fine, but *Wereldoorlog 2*, a direct translation of English *World War 2*, is not) or how speakers talk about past centuries (one would say *de achttiende eeuw* ‘the eighteenth century’ in Dutch, whereas *the 1700s* is also possible in English). We did not investigate the differences in detail, but expect the occurrence of such forms in child-directed speech to
consider *eerste* ‘first’ to be a superlative adjective, rather than an irregular ordinal; *eerste* shares a number of syntactic properties with superlatives that ordinals do not.\(^5\)

Table 1 provides an overview of synthetic (morphological) ordinals, but both languages also have the option of deriving ordinals syntactically to express ordinality, such as *hoofdstuk drie* ‘chapter three’ (cf. Hurford 1987; Barbiers 2007).\(^6\) As Barbiers (2007) points out for Dutch, analytic ordinals differ from synthetic ordinals in both form and meaning: synthetic ordinals have a context-dependent reference (like definite descriptions do) whereas analytic ordinals have a constant reference like proper names do. For example, *door (number) three* might be the second door that is opened in the classic Monty Hall problem, or *participant vier* ‘participant four’ might actually be the tenth participant you ran for your language acquisition experiment. The sentences in (2) through (5) compare analytic ordinals to synthetic ordinals and proper names in both Dutch and English.

(2)  
\begin{enumerate}
\item *(Het) vijfde boek verscheen in 2000.
\item *(The) fifth book appeared in 2000.
\end{enumerate}

(3)  
\begin{enumerate}
\item *(Het) boek vijf verscheen in 2000.
\item *(The) book five appeared in 2000.
\end{enumerate}

(4)  
\begin{enumerate}
\item *(De) Violet is slimmer dan de graaf.
\item *(The) Violet is smarter than the count.
\end{enumerate}

be minimal. Another difference is the relatively high frequency of *tiende* compared to *tenth* in English and the immediately preceding ordinals in Dutch. We can only guess: fractions (*drie tiende* would result in a hit for Dutch, but *three tenths* would not in English), spelling/parsing errors (e.g., *vijftiende* misspelled as *vijf tiende*, whereas *teenth* is unlikely to appear on its own), or the inclusion of sports commentaries in the Dutch corpus (where top ten lists are intuitively likely to occur) might account for some of these differences.

\(^5\) Whereas *eerste* can modify plural nouns, lose its final schwa (*eerst* ‘first’, but *achtst ‘eighth’), and be intensified by *aller–* ‘very’ (*allereerste* ‘very first’, but *allerachtste* ‘very eighth’), ordinals cannot. Diachronically, *eerste* also had (and to some extent still has) recognizable and regular degrees of comparison: positive *eer* ‘fore’ and comparative *eerder* ‘former’.

\(^6\) We are aware that some adult speakers of both Dutch and English might require a certain context or situation to use analytic forms, and/or the use of the noun *nummer/number* to make the utterances more natural. However, as the results will show, these forms were unproblematic for the children we tested. We therefore put concerns regarding unnaturalness in our test design or outcome aside for now.
(5)  a. (*De) Graaf Tel is grappig maar Graaf Olaf is een engerd.
b. (*The) Count Count is funny but Count Olaf is a creep.

These examples show that while synthetic ordinals precede the noun and require a (definite) determiner, analytic ordinals follow the noun and essentially take the place of the determiner (which is obligatorily absent, as is the ordinal suffix). Barbiers (2007), citing Siloni (1994) and Longobardi (1994), therefore tentatively suggests that in analytic ordinals, the head noun raises to D, similar to the N-to-D movement in construct states. Though Barbiers (2007) does not provide a full analysis (and neither will we), this type of analysis has also been proposed for related constructions in Dutch, namely title constructions, such as those provided in (6) for comparative purposes, and date constructions, such as drie februari ‘three February’ versus de derde februari ‘February third, lit: the third February’, which both mean February third (De Belder 2007, 2009). We leave the (analysis of) similarities and differences for future research to explore, but introduce the analytic forms here because they seem to behave similarly in Dutch and English, and address an important issue we briefly mentioned above: they help to disentangle effects of form (transparency, and morphology versus syntax) and frequency.

One final note on form: we take irregular ordinals in acquisition to be any ordinal that is not analytic and does not immediately and straightforwardly follow from adding a suffix –de (for Dutch) or –th (for English) to a cardinal base. Though theoretically not all irregular ordinals are equal (irregularity could be merely phonologically driven, a case of root allomorphy, or a case of suppletion), second, third, fifth and derde ‘third’ are all considered (equally) irregular in our analysis. There are two reasons for this, one practical one and one that is more hypothesis-driven. For one, each type of irregularity occurs only once, immediately confounding the type of irregularity with at least the place of the numeral in the count list and the frequency of that numeral. This makes it practically impossible to relate potential differences (or similarities!) in comprehension between second and fifth to the type of irregularity. Though it might be tempting to expect fifth to be easier to recognize, it is also further down the list and much less frequent than second or third and

7 A full comparative analysis of synthetic and analytic ordinals might also address archaic or literary forms of the type book the third, as found for example in Lemony Snicket’s A Series of Unfortunate Events or Charles Dickens’ A Tale of Two Cities.
we have no a priori way to determine how these factors interact with each other. Second, if the working hypothesis described above is that ordinal acquisition is rule-driven and ordinals are acquired ‘from the inside out’ (the meaning of the whole is acquired by acquiring the meaning of its parts), then any deviation from the rule is essentially problematic because it requires more than adding or subtracting an ordinal suffix. For Dutch, there is also the question of which ordinal suffix is the default option, since Dutch has two ordinal suffixes. There could be a case for arguing that *achtste* ‘eighth’ is the only regular ordinal under 20 (as *–ste* attaches to more stems than *–de*), but given that learners form rules on the basis of the input (and not all possible input), and the frequency data (Table 1) suggest that ordinals ending in *–ste* are even more scarce than ordinals with *–de*, we take *achtste* ‘eighth’ to be irregular here, despite the fact that it is morphologically decomposable into a transparent stem and an ordinal suffix.

4. Hypotheses and predictions
The present study investigates the hypothesis that children make use of the ordinal form to acquire ordinal meaning (put forward in the previous chapters), extends its linguistic domain from Dutch to English, and pits this view against frequency (and, indirectly, type-specific meaning). For both languages, we test cardinal knowledge as a reference point to which we can compare children’s ordinal knowledge. We focus on comprehension. Obviously, we expect no remarkable differences in cardinal knowledge between Dutch and English learners (though English learners might be somewhat quicker, cf. Chapter II). We also do not expect differences between the Dutch children in the current study and earlier studies reporting on Dutch children’s ordinal performance — at least for the same condition types. Thus, we expect to find an effect of (ir)regularity in synthetic ordinals, as well as an effect of knower-level and/or age. Moreover, regularized *driede* ‘threeth’ should not pose a problem for children who understand other regular ordinals, even if *derde* ‘third’ does: though absent from the input, this ungrammatical form does follow the ordinal formation rule the children are hypothesized to have formulated.

If English-speaking children acquire ordinals in the same way Dutch learners do, then we predict a clear effect of (ir)regularity here, too: we expect children to do better on regular ordinals than on irregular ordinals. And here, too, ordinal comprehension should arise around the
CP-knower stage of cardinal acquisition, and hence we expect an effect of knower-level and/or age (the two have been shown to be correlated (Chapters II and III). This means that performance on specific ordinals between the languages should differ: because Dutch tweede ‘second, lit: two–th’ is regular, performance here should be higher than on English second, which is irregular. Overall (on all ordinals combined), this means that English learners should do worse than Dutch children, because they have more irregular forms (exceptions) to acquire, which need to be learned lexically. If the number of exceptions affects the speed of acquisition of the rule, then English learners should not only have lower comprehension scores on irregular forms, but also on regular forms. Note, though, that acquisition speed need not be affected; perhaps the English learners receive sufficient input despite these exceptions — more evidence does not necessarily imply quicker or easier acquisition.

However, it may be that the number of exceptions in the English ordinal list discourages a rule-based approach to ordinal acquisition altogether. In this case, English learners could fall back on other properties, such as token frequency. Then we expect (at least the first five) ordinals to be acquired lexically. Differences in scores on individual ordinals would then not be the result of their irregularity, but of their place in the count list (as lower ordinals are more frequent than higher ordinals). Higher ordinals could then be acquired either via a rule or lexically. Moreover, if Dutch learners are typically helped by the ordinal rule, and English learners cannot benefit from such a rule, then we expect lower scores overall in the English group. Put differently, English learners would be slower than Dutch learners. Adult speakers of English obviously do derive ordinals via a rule (and hence have accrued enough evidence); the issue is whether children are able to take in or treat sufficient positive evidence from the input to form a rule at all.

We can use the Tolerance Principle and the Sufficiency Principle to determine when children (or adults) will form a rule, given the (counter) evidence the learner has (Yang 2016). These principles state

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8 See Yang (2016) for the full derivation and motivation for these principles and formalisms, as well as morphological, syntactic and prosodic examples that follow these principles. Basically, the focus is on the break-even point between storage and computation, i.e., the time it takes to store all items lexically versus the time needed to form a productive rule. If a rule is productive, the learner cannot apply it until all exceptions have been considered and rejected. The time it takes to consider each exception depends on its frequency (rank in the list of exceptions, which follows an assumed Zipfian distribution). Hence, \( e \) in the formulas in (6) and (7) could be read as...
that a rule can and will generalize if, and only if, (i) the number of explicitly attested exceptions is lower than the number of items in the category $N$, divided by the natural log of $N$, and (ii) the number of rule-following attestations subtracted from the total number of items in the category $N$ is lower than the number of items in the category $N$, divided by the natural log of $N$. This is formalized as in (6) and (7).

(6) The Tolerance Principle (Yang 2016:8)
“If $R$ is a productive rule applicable to $N$ candidates, then the following relation holds between $N$ and $e$, the number of exceptions that could but do not follow $R$:

$$e \leq \theta_N \text{ where } \theta_N = \frac{N}{\ln N}.$$ 

(7) The Sufficiency Principle (Yang 2016:177)
“Let $R$ be a generalization over $N$ items, of which $M$ items are attested to follow $R$. $R$ can be extended to all $N$ items if and only iff:

$$N - M < \theta_N \text{ where } \theta_N = \frac{N}{\ln N}.$$ 

Although at first glance the two principles might seem identical, the formalisms are different for a reason: whereas the Tolerance Principle is an evaluation measure focused on explicit counterevidence for a given rule $R$ (the exceptions), “Sufficiency, by contrast, asserts that unless the Sufficiency threshold has been crossed, learners are in a state of ambivalence regarding the $(N - M)$ items with which they have no direct experience.” (Yang 2016: 178) In other words, children do not generalize a rule to unattested forms if the sufficiency threshold is not met. The two principles balance out how much evidence is enough to generalize over unknown forms, and how much counterevidence is tolerable to maintain a given rule. Note that the outcome (rule or no rule) depends on the amount of evidence a learner has at any given time (here: vocabulary size).

Given these principles, children would only need to know five ordinals total in order for English ordinal formation to be considered productive in children, despite the exceptions second, third and fifth. (If $N = 5$, then $\theta_5 = 3.1$, which is greater than 3.) This means that just two regular ordinals (e.g., fourth and sixth) would then be enough to acquire a unit of time, and the formalisms as a more mathematical approach to the Elsewhere Condition (Anderson 1969; Kiparsky 1973).
the ordinal formation rule. If first is considered a candidate for the rule $R$ (bringing the number of exceptions up to four), then the total number of $N$ candidates must be nine, meaning now five rule-abiding forms are necessary. Either case would require the English learner to be in the CP-knower domain to know a sufficient number of cardinal roots to which the rule could apply. This would require the learner to somehow store evidence for the rule before actually being able to use the ordinal forms it has stored (as previous work provided no evidence for an initial stage of lexical acquisition of derde ‘third’ in Dutch).\textsuperscript{9,10}

Another issue we need to address is how to explore the roles of form (transparency, and morphological and syntactic ordinals) and frequency. We use highly regular and transparent analytic ordinals (of the type chapter three) for this purpose. Transparency plays an obvious role in the case of irregular synthetic ordinals: if transparency is key, learners (in both language groups) should find analytic ordinals easier to understand than irregular synthetic ordinals. Regular synthetic ordinals (morphological, vierde auto ‘fourth car’) and analytic ordinals (syntactic, auto vier ‘car four’) are expected to be equally transparently related to the cardinal, and we therefore expect no differences in performance on the basis of transparency. However, these ordinal types do differ with respect to their form (synthetic ordinals require the use of the suffix but not movement, whereas analytic ordinals require movement but no suffix), and their prevalence in the input. We are assuming that, for the purpose of this study, the (minor) semantic differences will not play a role (though

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\textsuperscript{9} Note that the Dutch learner almost gets the rule for free, because (as Yang points out) learners with small vocabularies (small $N$s) have a better chance of formulating a rule (small $N$s skew towards rule-formation and tolerate a relatively large amount of exceptions).

\textsuperscript{10} The absence of this initial stage is motivated by the comprehension difficulties that go hand in hand with derde ‘third’. Typically, when rules are involved in the acquisition of morphemes, we are looking at a u-shaped or ‘change for the worse’ pattern in development, with the prototypical example being overgeneralizations in irregular past tense forms: the child initially says went and ate, then temporarily also starts producing *goed and *eated, before the evidence steers him back towards targetlike production (e.g., Marcus, Pinker, Ullman, Hollander, Rosen & Xu 1992; Pinker 1999). However, it seems unlikely these children would have difficulty comprehending went in the *goed stage, especially since the irregular forms never disappear entirely from the output. Consequently, ordinal acquisition is also unlike acquiring inflectional morphology (cf. Chapter III). Discussion of how inflectional morphology is represented, processed and acquired, and how this compares to the ordinals at hand, goes beyond the scope of the present paper.
arguably the semantic differences influence the contexts in which they can be used and thus their frequency). In other words, if frequency is most important, then (regular) synthetic ordinals should be easier for children to comprehend than analytic ordinals.

If the form itself matters (i.e., whether the ordinal is derived syntactically or morphologically), then we might expect one form to be preferred over the other. We have no clear predictions about whether suffixation (synthetic forms) or movement (analytic forms) would be easier, however. On the one hand, zero-derivation may be easier for children than affixation, which suggests the suffix in synthetic forms is a hurdle children need to overcome (see section 2 and Clark 2014). On the other hand, the head movement needed for analytic forms might also be problematic, as movement has been considered a costly operation in child language (cf. Blom & De Korte 2008; Zuckerman 2001 on verb movement and Dutch L1), and examples of such ordinal or similar constructions are scarce: they are likely limited to constructed names such as kabouter Spillebeen (Spillebeen the Gnome, lit: ‘gnome spindlelegs’, who features in a Dutch nursery rhyme) and titles (Willem II, ‘William the second, lit: William two’). No type of storage helps here: analytic ordinals must be derived and interpreted on the spot.

Including analytic ordinals also provides insight in the difference between grasping ordinals and grasping the ordinality principle. The reasoning in Chapter II is that children use and need the linguistic form to grasp ordinal meaning. If acquiring ordinality depends on a specific ordinal form, we expect differences in comprehension between synthetic and analytic ordinals. If ordinality does not hinge on any specific form (but on no form or simply having any cues), the precise labels (syntactic or morphological) should be of negligible importance as long as the relationship with the cardinal base is transparent. In short, we are pitting transparency and rules against frequency, expecting children to prefer a ‘mechanical’ relationship between the ordinal and the cardinal from which it is derived, acquiring regular forms first, and irregular forms lexically later on.

5. Study 1: Dutch comprehension

5.1 Method
We closely followed previous work on numerical development and adapted the ‘Give X’ comprehension task described in Chapter II. As described
there, we tested the ordinals *eerste* ‘first’ through *vierde* ‘fourth’, *zesde* ‘sixth’, *achtste* ‘eighth’ and *negende* ‘ninth’, and their corresponding cardinals (to assess a child’s knowers-level). In contrast to previous work, we further included the analytic ordinal forms for the numerals above, plus the ungrammatical but regular forms *eende* ‘oneth’, *eenste* ‘onest’, and *driede* ‘threeth’, and the superlatives *middelste* ‘the middle, lit: middle–est’ and *laatste* ‘last’. Each occurred three times. We also included six items that were introduced with an indefinite determiner *een* ‘a’ (e.g., *een hobbelpaard mag mee* ‘a rocking horse gets to come’). Each child was tested at their (pre)school in two twenty-minute sessions, administered within one week of each other. See the Appendix for a full list of stimuli and a description of the test orders.

The experimenter asked the child to help a toy monkey named Jaap pack for a trip. Jaap’s things (laminated cards with images of familiar objects and animals on them) were all getting in line to jump into the suitcase, and the child was asked to listen to what Jaap wanted and put the appropriate item(s) from the line in the suitcase. Examples (8) through (10) illustrate cardinal, synthetic ordinal and analytic ordinal stimuli, respectively.

(8) Er mogen acht stiften mee. Kun je acht stiften
There may.pl eight markers with. Can you eight markers
(tellen en) inpakken voor Jaap?
(count and) pack for Jaap?
‘Eight markers get to come. Can you (count and) pack eight markers for Jaap?’

(9) Jaap zegt dat de zesde jas mee mag.
Jaap says that the sixth coat with may.sg.
Jaap says that the sixth coat gets to come.

Kun je de zesde jas (vinden en) inpakken voor
Can you the sixth coat (find and) pack for

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11 This *een*-condition was included because of the ‘first bias’ (Chapter II) found in children who only understand that ordinals referred to individual items: roughly half of these children always selected the first card, regardless of the ordinal. We consider this *een* condition neutral, and hence expect a bias to appear only if it is the result of a more general strategy, not if it is driven by something related to the ordinal itself.
Jaap says that the sixth coat gets to come. Can you (find and) pack the sixth coat for the monkey?

(10) Jaap zegt dat slang drie mee mag.
Jaap says that snake three with may.sg.
Jaap says that snake three gets to come.

Kun je slang drie (vinden en) inpakken?
Can you snake three (find and) pack
‘Jaap says that snake three gets to come. Can you (find and) pack snake three?’

Though the exact formulation varied to keep the game natural, typical stimuli offered children the numeral in a full subject DP. When necessary, the numeral was repeated with either a noun (with cardinals, e.g., negen ballonnen ‘nine balloons’) and/or a definite article (with ordinals, e.g., de tweede (slee) ‘the second sled’). Children were allowed to count out loud, use their finger to track the objects they counted, and recount (“check and make sure”).

The objects for ordinal trials were all identical, depicted from the side and had clear fronts or faces to highlight the direction of the line. The number of objects in line varied per numeral: the lowest numeral trials (one, two, first and second, car one, car two) all occurred with four cards in line; cardinals three, four, and their ordinal counterparts with six cards, and the higher numeral conditions with ten. We presented items in one of eight pseudo-random orders within each session and we counterbalanced which session was administered first between participants. Both sessions started with two stative locative PP’s as practice items (in which children had to find the object vooraan ‘at the front’ and achteraan ‘at the back’ of the line), and typically ended with a counting session, in which children were asked (to try) to recite the cardinal count list, followed by the ordinal list. They were allowed to use the cards to perform these counting tasks.

12 N-ellipsis should not be an issue because (i) the initial stimulus does contain the full DP and (ii) children as young as 1;8 can use e.g., cardinals, quantifiers, superlatives and/or eerste ‘first’ to license N-ellipsis in their own speech (Sleeman & Hulk 2013).
Children who declined to count were not excluded from analysis as long as they completed the rest of the task.

We first looked at the responses to the cardinal trials to determine each child's cardinal knowledge, by using the knower-level estimation tool provided by Negen, Sarnecka & Lee (2012, based on Lee & Sarnecka 2010ab) and the criteria described in e.g., Le Corre & Carey (2007). To be considered a 'knower' of a given cardinal under these criteria, a child had to provide the correct number of cards for a given cardinal at least two out of three times when asked for that cardinal, and provide that number of cards no more than once in response to a different cardinal. The tool and the criteria typically led to the same categorization. We gave the child the benefit of the doubt in the few cases where there was a difference and/or where the model was inconclusive (mostly due to issues involving minor counting errors on high cardinals.) Three children had to be excluded because their response patterns were so erratic that a knower-level classification was not possible. We determined children's ordinal knowledge in the same way as in Chapters II and III, i.e., by only taking correct responses into account. 13 We considered a total of 70 typically-developing monolingual Dutch children (38 boys, 32 girls; ages: 32–59 months, $M = 48.7$, $SD = 8.3$) for analysis.14 We excluded an additional six children for not completing all trials.

5.2 Results

The data from the indefinite een 'a' baseline condition reveal no issues with basic components of the task, and no children were excluded from further analysis on the basis of these trials. When asked to provide, for example, een helicopter 'a helicopter', most children (83%) always provided a correct response. Only 7 children (10%) provided more than one card on half (or more) of these trials. Such errors make up 8.3% of the total number of responses to een 'a' trials. We found no correlations with age or any other

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13 The reasoning is that ordinal acquisition does not appear to be inherently tiered, and thus we have no way to properly interpret or weight an error. For cardinals, if a child provides e.g., six cards when asked for three, he not only lacks knowledge of three but also of six. For ordinals, by contrast, if the child provides the sixth card when asked for the third, we can only be sure he does not understand third.

14 Children were not pre-tested for language or developmental disorders within the context of this study. We considered children to be typically developing on the basis of teacher assessments and if they were not enrolled in speech therapy or remedial classes, and were not being screened for language or developmental disorders.
factors. We did find that 47% of children preferred the first card in line, meaning that they selected the first card on more than half of the een-trials. This is in line with what Chapter II describes for responses to ordinals among subset-knowers, where roughly half the children exhibit what they call a “first-bias”.

Before turning to ordinals, we first need to assess children’s cardinal knowledge. Table 2 displays children’s ages at each cardinal knower-level; Figure 1 is an area plot of the knower-levels by age.

Table 2: Knower-level and age of all participants. Age ranges and means are given in years (year:month) and months, the standard deviations in months only.

<table>
<thead>
<tr>
<th>Levels</th>
<th>n</th>
<th>Age Range</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-knowers</td>
<td>3</td>
<td>2;11–3;03 (35–39)</td>
<td>3;01 (36.7)</td>
<td>2.1</td>
</tr>
<tr>
<td>1-knowers</td>
<td>10</td>
<td>2;09–4;01 (33–49)</td>
<td>3;03 (38.7)</td>
<td>5.7</td>
</tr>
<tr>
<td>2-knowers</td>
<td>7</td>
<td>2;08–4;05 (32–53)</td>
<td>3;05 (41.3)</td>
<td>7.2</td>
</tr>
<tr>
<td>3-knowers</td>
<td>2</td>
<td>3;01–3;06 (37–42)</td>
<td>3;04 (39.5)</td>
<td>3.5</td>
</tr>
<tr>
<td>4-knowers</td>
<td>7</td>
<td>3;06–4;10 (42–58)</td>
<td>4;04 (51.7)</td>
<td>6.0</td>
</tr>
<tr>
<td>CP-knowers</td>
<td>41</td>
<td>3;06–4;11 (42–59)</td>
<td>4;05 (53.2)</td>
<td>5.1</td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td>2;08–4;11 (32–59)</td>
<td>4;01 (48.7)</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Figure 1: Area plot of knower-level distribution in the Dutch sample per age group.

Both the table and the figure paint a familiar picture: the distribution of children across knower-levels and age groups resembles what was previously described for Dutch in Chapters II and III. As in Chapter III, the number of four-knowers is relatively limited and the number of CP-knowers relatively high compared to Chapter II, but the overall picture is otherwise comparable and more in line with what was attested for studies focusing on e.g., English. While there is some individual variation with respect to the age at which children are at a certain knower-level, a Spearman’s correlation test reveals that children’s cardinal knowledge
correlates significantly with their age in months ($r_s=0.692$, $p<0.001$). Most of the individual variation is found in three-year-olds, as nearly all four-year-olds have reached (or nearly reached) the final stages of cardinal acquisition, while no children younger than 3;06 can be classified as four-knowers or CP-knowers.

Given the similar situation (our dataset only includes ordinal type as an extra factor), we follow a similar statistical procedure to the one in Chapter II. We used R (R Core Team 2016) and the lme4 package to fit a generalized linear mixed-effects logistic regression model (Bates, Maechler, Bolker & Walker 2015) to the data described above. We worked towards a final model in a few steps. We first excluded the synthetic and analytic forms for the first in line (i.e., *eerste*, *eende*, *eenste*, and *auto één*), as well as the superlative *laatste* ‘last’.\footnote{Again, we left out *eerste* ‘first’ for a priori conceptual reasons: *eerste* ‘first’ is a superlative, not a true ordinal (cf. Barbiers 2007).} All other synthetic and analytic ordinals we tested were included. We then constructed a model with a random effects structure that was as maximal as our data would justify. We included by-subject random intercepts with slopes for ordinal (place in the count list) as a continuous factor and ordinal type (synthetic, e.g., *vierde auto* ‘fourth car’, or analytic, e.g., *auto vier* ‘car four’), and by-trial random intercepts with slopes for AgeInMonths*Knower-level.\footnote{Including random slopes for regularity led to convergence errors, as did interactions between ordinal and type. Including ordinal as a categorical factor here led to convergence errors in some steps. We opted to simplify the model rather than eliminate the random slopes completely.} We included as fixed factors ordinal, ordinal type and regularity (irregular, i.e., *derde* ‘third’ and *achtste* ‘eighth’, or regular, such as *vierde auto* and *auto vier*; all analytic ordinals are inherently regular) and knower-level (continuous) in the initial model. The dependent variable was whether a child’s response was correct or incorrect, meaning the formula for this initial model is \[ \text{Correct} \sim \text{OrdinalContinuous} + \text{Regularity} + \text{Type} + \text{Knower-level} + (1 + \text{OrdinalContinuous} + \text{Type} | \text{Subject}) + (1 + \text{Knower-level}^* \text{AgeInMonths} | \text{Trial}) \]. We centered continuous factors and coded categorical factors with explicit contrasts before analysis. No outliers other than those described above were removed.

If we were to follow Chapter II, we would go on to investigate whether a child’s age was a better predictor for ordinal comprehension than knower-level, comparing a model similar to the one above with one
in which knower-level was exchanged for age in months because the two factors are correlated. Following this strategy with our data does show that knower-level is a better predictor than age (model with knower-level: AIC: 1792.8, BIC: 1916.9; model with age: AIC: 1809.2, BIC: 1933.4), however, we here included both knower-level and age as factors, as well an interaction between these two in the same model. This made the model more complex (Correct ~ OrdinalContinuous + Regularity + Type + Knower-level*AgeInMonths + (1 + OrdinalContinuous + Type | Subject) + (1 + AgeInMonths*Knower-level | Trial)) but led to a significant improvement over the model without age (AIC: 1788.6, BIC: 1924.5; χ² = 8.2246, df = 2, p = 0.01637), despite the correlation between age and knower-level (correlation of the coefficients for age and knower-level: – 0.602).

We then compared this model to one in which ordinal as a continuous factor and regularity are replaced by one in which ordinal is a categorical factor: Correct ~ OrdinalCategorical + Regularity + Type + Knower-level*AgeInMonths + (1 + OrdinalContinuous + Type | Subject) + (1 + OrdinalContinuous + Type | Trial). The reasoning, following previous work, is that a simpler model containing ordinal as a continuous variable may not suffice to explain the variance in our data: ordinal is not truly a continuous variable, and it might be that ordinals are acquired at random (and not simultaneously or in order). Moreover, if something about the individual ordinals themselves better explains the data than what we have defined as irregular, then a more complex model with ordinal as a categorical factor should explain more variance. However, the model comparison reveals this is not the case; the more complex model has an AIC of 1801.6 and a BIC of 1955.3, and thus offers no improvement. We therefore retain the model in Table 3, in which ordinal is a continuous factor.17

17 Note that we have taken achtste ‘eighth’ to be irregular in the analysis above. Recoding achtste ‘eighth’ as regular did not affect the outcome in the sense that both models show the same effects to be (in)significant, and in the same direction.
Table 3: Result summary for correct responses on tested ordinals in Dutch: $\beta$ coefficient estimates, confidence intervals, standard errors, associated Wald's z-score and significance level ($p$) for all predictors in the analysis. Formula: Correct $\sim (\text{OrdinalContinuous} + \text{Regularity} + \text{Type}) + \text{Knower-level}\ast\text{AgeInMonths} + (1 + \text{OrdinalContinuous} + \text{Type} | \text{Subject}) + (1 + \text{Knower-level} * \text{AgeInMonths} | \text{Trial})$. Ordinals considered irregular: derde ‘third’ and achtste ‘eighth’.

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimate</th>
<th>CI</th>
<th>SE $\beta$</th>
<th>$z$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.063</td>
<td>-0.952 – 1.078</td>
<td>0.518</td>
<td>0.122</td>
<td>0.9029</td>
</tr>
<tr>
<td>Ordinal</td>
<td>-0.271</td>
<td>-0.374 – 0.168</td>
<td>0.053</td>
<td>-5.145</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Regularity</td>
<td>0.950</td>
<td>0.397 – 1.503</td>
<td>0.282</td>
<td>3.369</td>
<td>0.0008</td>
</tr>
<tr>
<td>Type</td>
<td>-0.448</td>
<td>-0.896 – 0.005</td>
<td>0.228</td>
<td>-1.958</td>
<td>0.0502</td>
</tr>
<tr>
<td>Knower-level</td>
<td>1.669</td>
<td>1.036 – 2.303</td>
<td>0.323</td>
<td>5.164</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age</td>
<td>0.080</td>
<td>-0.026 – 0.186</td>
<td>0.054</td>
<td>1.474</td>
<td>0.1406</td>
</tr>
<tr>
<td>Knower-level $\ast$ Age</td>
<td>0.074</td>
<td>0.015 – 0.133</td>
<td>0.030</td>
<td>2.447</td>
<td>0.0144</td>
</tr>
</tbody>
</table>

The model reveals significant main effects of ordinal, regularity and knower-level, and a significant interaction between age and knower-level, but no significant main effect of age. Put differently, what matters in ordinal comprehension is the place in the ordinal count list (higher ordinals are less likely to elicit a correct response) and whether the form follows a regular ordinal formation rule. Whether that is a syntactic rule yielding an analytic ordinal such as *auto vier* ‘car four’ or a morphological rule yielding the synthetic ordinal *vierde auto* ‘the four car’, does not significantly affect probability of a correct response, though the trend is in favor of synthetic forms (see also Figure 3). It does not generally hold that older children are more likely to provide correct responses. The interaction effect (see Figure 2) clearly shows that age only affects performance in children who have substantial cardinal knowledge in place, and that cardinal knowledge only matters for the two highest knower-levels. Figure 3 shows the proportions of correct responses for both ordinal types by knower-level in the raw data.
Figures 2 and 3 show that pre-to-three knowers have great difficulty comprehending ordinals in general, regardless of their age. By contrast, age effects do appear for the highest two knower-level categories, where four-knowers perform somewhere in between lower subset knowers and CP-knowers. The difference is particularly large at the high end of the age range; while younger CP-knowers need not necessarily outperform four-knowers, this does hold for the oldest age groups. CP-knowers score significantly higher than four-knowers (Mann-Whitney $U = 101538$, $Z = -14.157$, $p < 0.0001$, two-tailed), and ceiling scores do not appear before the CP-knower stage.
Note that only four of the pre-to-three-knowers provide the correct response to a given ordinal more than once, and only one does so for more than one ordinal. We therefore conclude that children in these lower subset-knower stages lack (systematic) ordinal knowledge. Though not visible in the figures, pre-to-three-knowers do seem to know that an ordinal refers to an individual, since they only select one item from the line.

Figure 4 depicts the percentage of correct scores CP-knowers provided for each cardinal and ordinal included in the model, as well as the superlatives eerste ‘first’, middelste ‘mid’ and laatste ‘last’, and in het midden ‘in the middle’, which here is plotted as the analytic variant to indicate where the middle is. We did not include these latter forms or the raw cardinal scores in the model, but we provide them here for comparative purposes, as they show that performance here was consistently high.

The first observation is that even though CP-knowers are considered to understand all cardinals, performance does decrease for higher cardinals (lightest bars). This pattern is different for ordinals: though performance is better on tweede ‘second’ and vierde ‘fourth’ than on the three highest ordinals, performance on these highest ordinals is stable, even for achtste ‘eighth’. Second, as the model indicates, we see no difference in correct
responses between regular synthetic (medium gray bars) and analytic ordinal forms (darkest bars): both negende auto ‘ninth car’ and auto negen ‘car nine’ are equally comprehensible, for example. The most important results, however, pertain to ordinals for three, where the effect of irregularity mentioned above is visible. Children find the derde ‘third’ less often than *driede ‘threeth’, and the neighboring ordinals tweede ‘second’ and vierde ‘fourth’. No difference is found between the responses to *driede and auto drie.\textsuperscript{18} In total, 13 CP-knowers were unable to find the derde ‘third’. Four of them had difficulty on all ordinals included in the model, but the other nine were able to respond correctly to tweede ‘second’, *driede ‘threeth’ and vierde ‘fourth’ on (at least) two out of three trials, as well as *driede. No children knew only one of the regular low ordinals, and children performed consistently on 98% of conditions (i.e., responded correctly on all trials in a given condition, or incorrectly on all trials in a given condition). Put differently, the transparent lower ordinals lead to similar performance, whereas irregular derde trails behind. Patterns in the higher ordinal set are less clear, and less consistent overall (with 3/3 or 0/3 correct on a given condition 80% of the time), but there were no children who exhibited better performance on the three highest ordinals than the lowest ones, and only two children with isolated difficulty with achtste ‘eighth’.

As reported in earlier work (see also section 3), many children would count on these and other ordinal trials, either silently or out loud. For example, when asked for the vierde ‘fourth’, many children would simply count to four and pack the fourth card, sometimes explicitly adding the ordinal or a concluding remark such as dit is de vierde ‘this is the fourth’. They would then also seem to apply this strategy to derde ‘third’; some would ask hoeveel is der ‘lit: how many is thir’ or wat is der ‘lit: what is thir’, and/or would count (and re-count) the objects in line, sometimes concluding die zit er niet bij ‘that one isn’t there’ or die weet ik niet ‘I don’t

\textsuperscript{18} A reviewer requested an additional analysis zooming in on effects of transparency on the ordinals derde, driede and auto drie in CP-knowers. In order to take random effects into account, we ran an additional model on this subset of the data with ordinal form as a categorical factor. We set explicit treatment contrasts with derde as a baseline compared to *driede and auto drie, and otherwise kept the formula close to the original: Correct ~ Form + AgeInMonths + (1+Type|Subject) + (1 + AgeInMonths|Trial). The effect of form was significant for derde versus driede ($\beta = 7.616$, CI= 1.899 – 13.333, SE = 2.917, Z = 2.611, $p = 0.0090$) but not for the difference between derde and auto drie ($p = 0.1898$) or for age ($p = 0.3132$). The difference in Figure 4 can therefore be attributed to factors included in the random structure.
know that one’, or openly admitting to guessing or applying some strategy (e.g., it has to be the last card because they know the others are the tweede, *driede, vierde ‘second, *threeth, fourth’ et cetera). In contrast, mistakes on higher ordinals were never accompanied by such questions or explicit explanations.

5.3 Discussion
The data above go against any kind of lexical learning, and instead are in line with a rule-driven pattern in acquisition. If lexical learning had been at play, we would have expected better performance on derde ‘third’ than on vierde ‘fourth’, and not a pattern in which many children cannot find the third item in line but can find its neighbors. The relatively high and consistent performance on analytic ordinals (jas zes coat six’) is also unexpected under a lexicalist approach: these forms are all but absent from the input, and should at least elicit fewer correct responses than synthetic ordinals (zesde jas ‘sixth coat’). Perhaps the most telling evidence, though, comes from children’s confused responses to irregular derde ‘third’: overgeneralization and backformation is unexpected from a perspective in which children store initial forms as simplex rather than complex forms.

Instead, the data align more neatly with previous work that argues in favor of a rule-based pattern. A rule can account for the difference in performance between derde ‘third’, and regular(ized) forms such as tweede ‘second’, *driede ‘threeth’ and vierde ‘fourth’, and the accompanying verbal reactions. Children’s questions and comments on these trials suggest that the allomorph obscures the relationship with the cardinal drie ‘three’, which leads to comprehension difficulties on these trials. (Note that this goes against any kind of ‘change for the worse’ or U-shaped pattern, as it is unlikely for children to forget a previously stored form.) These comprehension difficulties disappear when the opacity is resolved: analytic auto drie ‘car three’ and the regularized yet ungrammatical synthetic form *driede ‘threeth’ elicited more correct responses. Moreover, a rule-based account also explains a relatively ‘flat’ level of performance across all the higher ordinals, as well as the consistent responses on analytic ordinals such as auto drie ‘car three’: application of a rule should lead to consistent performance. However, such an account does leave us with a question, for precisely this reason: why is performance on higher ordinals lower than performance on tweede ‘second’ and vierde ‘fourth’?
Surely, children who know a rule should be able to apply this rule across the board.

Note though that the difficulty appears after the same cutoff point in cardinal knowledge, namely the difference between ‘low’ (≤4) and ‘high’ numerals. (We say appears because we did not test *vijfde* ‘fifth’, unfortunately.) There were no CP-knowers who only knew one of the regular low ordinals, so it seems that at least these regular forms are acquired simultaneously. Hence, one way to account for this difference between lower and higher ordinals in the present study, is to say that these children do have a rule, but (can) only apply this rule within the OTS domain initially. For *vierde* ‘fourth’ only the Object Tracking System is needed, whereas both systems are required to reach an exact interpretation for higher ordinals. The learner needs the ANS to represent the larger set and the OTS to represent the individual within that set. As a result, difficulty with higher ordinals arises from having to integrate (co-activate) both core knowledge systems of number in addition to applying the ordinal formation rule. Put differently, some CP-knowers can either apply the rule within the OTS limits (ordinals ≤4), or co-activate ANS and OTS (cardinals ≥4), but not both.

This explanation supposes that applying the ordinal rule to higher numerals requires bridging the same critical gap subset-knowers have to bridge to become CP-knowers in cardinal acquisition, which in turn means that combining ANS and OTS is not something the learner does just once, but has to do iteratively. The added difficulty of integrating both systems is equal for all ordinals, which explains why performance across higher ordinals is equal, and would explain why this effect was not found in Chapter III: those children were six months older on average, and the only ordinal with which those children had difficulty comprehending was *derde* ‘third’. Future research would be needed to determine how robust this effect is and whether it is, for example, a relatively short stage limited to children who have just become CP-knowers or whether it is found over prolonged periods of time in all types of CP-knowers. Moreover, though there is a large body of (both behavioral and neural) work that shows ANS functions independently from OTS (in line with the idea that ANS and OTS are not truly ‘integrated’), the details of numerical ordinal processing and development have received far less attention (Geary & Moore 2016, Lyons, Vogel & Ansari 2016).

We can now maintain that children first recognize that the ordinal *vierde* ‘fourth’ consists of a cardinal root *four* and a suffix –*th*. They also
need to learn (to apply) the relevant counting principles to the root, before they can add on the semantic contribution of the ordinal suffix (or, in the analytic case, of the effect of raising the noun past the numeral) and arrive at the interpretation of the whole. If they did not need such principles, more subset-knowers would be able to comprehend at least some ordinals, not just older four-knowers (who are perhaps on the cusp of acquiring the cardinal principle anyway). An open question is whether the OTS limit is a conceptual or a practical issue here (i.e., whether the ordinal rule initially only applies within OTS limits, or whether it applies to all cardinals but fails). If it is conceptual, then that would mean children who have difficulty combining OTS and ANS cannot use evidence from higher ordinals in the input for their ordinal rule.

However, evidence from higher ordinals would not be strictly necessary for Dutch children. Following Yang (2016) as discussed above, two ordinals suffice to offset the single exception (or even two exceptions, if *eerste* ‘first’ must be considered an ordinal). Children can thus use the two regular ordinals as evidence for their rule, and generalize over these examples before actually understanding the meanings of the whole. Again, this goes against the claim in Clark (2014), that when it comes to derivational morphology, children learn individual (complex) forms lexically at first, and only form a productive rule after sufficient examples of such a rule are stored.

The fact that the other ‘exception’ to the rule, *eerste* ‘first’, is acquired early is no surprise: *eerste* ‘first’ is a superlative, not an ordinal (cf. Barbiers 2007), meaning access to the cardinal root is irrelevant and determining the first in line is procedurally less complex (no counting). Something similar holds for *laatste* ‘last’ and *middelste* ‘lit: middle-st’: again neither counting, ordinal morphology, nor set size is relevant for these trials. This makes them more like the stative locative PP’s *voor/aan* ‘at the front/at the back’ we incorporated as practice items, and with which children experienced very little to no difficulty. Hence, it is also no surprise that *in het midden* ‘in the middle’, an analytic alternative to *middelste*, is unproblematic. Further research would need to explore when stative locative expressions are acquired.

The question is now to what extent a rule-based approach to ordinal acquisition holds for English. The evidence for the ordinal formation rule is more scarce in the English situation, which may make the lexical approach more attractive to the learner and/or influence the timing of English ordinal learning.
6. Study 2: English comprehension

6.1 Method

The English version of the task was designed to match the Dutch version as closely as possible, but was modified to better match the nature of the English ordinal list and shortened such that the task could be completed in two shorter sessions lasting a maximum of 20 minutes each. We therefore excluded indefinite trials, which were present in the Dutch task, as well as ungrammatical yet regularized stimuli. We included cardinals, synthetic ordinals, and analytic ordinals for the first seven numerals of the count list, plus the superlative last, which were all tested three times each. The total task consisted of 66 trials, two practice items before each session, and the counting routine at the end of each session. The task was procedurally identical to the Dutch version, as were the methods used to assess their cardinal and ordinal knowledge. See the Appendix for a full list of stimuli and a description of the test orders.

A total of 35 children were tested and considered for analysis (15 boys, 20 girls; ages: 39–63 months, $M = 51.3, SD = 7.0$). An independent samples t-test indicated that this sample does not significantly differ in age from the Dutch group ($t = 1.371(61.54), p = 0.175$, two-tailed). An additional 5 children were tested but excluded from analysis because they did not complete both sessions of the task. One child was initially included but was the only three-knower in a sample that otherwise (coincidentally) consisted of only CP-knowers. This child (3;06) answered incorrectly on all non-cardinal trials except those for one and last. All children were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschool. They were reported to be typically-developing and spoke English at home at least 70% of the time.

6.2 Results

We again turned to generalized linear mixed-effects logistic regression models to test the effects of the factors we also discussed for Dutch (R Core Team 2016, Bates et al. 2015). As before, we excluded the synthetic and analytic forms for first, as well as the superlative last, and included both synthetic and analytic forms for the six other ordinals in our experiment (second through seventh). We included by-subject random intercepts with slopes for ordinal (place in the count list) as a continuous factor and ordinal type (synthetic, e.g., fourth car, or analytic, e.g., car four) and their interaction, and by-trial random intercepts with slopes for age in months.
in all models, and the dependent variable in all models was whether a child’s response was (in)correct. This time, knower-level was not included in our analysis because all children included in this sample were classified as a CP-knower. We instead included age in months (continuous), in addition to ordinal (continuous), ordinal type (synthetic, e.g., *fourth car*, or analytic, e.g., *car four*) and regularity (irregular, such as *second*, or regular, such as *car two* or *fourth car*) as factors. We centered continuous factors and coded categorical factors with explicit contrasts before analysis. No additional outliers were removed.

As before, we began with a model that included interactions between age on the one hand, and ordinal and regularity on the other, plus their respective main effects. We also added ordinal type and an interaction between type and age. We then compared this model to one in which we replaced ordinal as a continuous factor and regularity by a categorical factor ordinal. However, as we saw with Dutch above, treating ordinal as a categorical factor does not lead to an improvement: the AIC and BIC in the more complex model are 998.71 and 1137.5 respectively, while those in the initial, more simple model are 977.01 and 1084.9. We thus retained the original model, as described in Table 4.

Table 4: Result summary for correct responses on 2nd – 7th in English: β coefficient estimates, confidence intervals, standard errors, associated Wald's z-score and significance level (p) for all predictors in the final analysis. Formula: Response ~ OrdinalContinuous + Regularity + Type + AgeInMonths + OrdinalContinuous: AgeInMonths + Regularity: AgeInMonths + Type: AgeInMonths + (1 + OrdinalContinuous*Type|Subject)+(1+AgeInMonths|Trial).

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimate</th>
<th>CI</th>
<th>SE β</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.049</td>
<td>-1.128 – 1.031</td>
<td>0.551</td>
<td>-0.088</td>
<td>0.9297</td>
</tr>
<tr>
<td>Ordinal</td>
<td>-0.212</td>
<td>-0.387 – -0.036</td>
<td>0.090</td>
<td>-2.362</td>
<td>0.0182</td>
</tr>
<tr>
<td>Regularity</td>
<td>2.201</td>
<td>-0.704 – 2.804</td>
<td>0.308</td>
<td>7.154</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Type</td>
<td>0.068</td>
<td>-0.578 – 0.715</td>
<td>0.330</td>
<td>0.207</td>
<td>0.8357</td>
</tr>
<tr>
<td>Age in months</td>
<td>0.096</td>
<td>0.067 – 0.259</td>
<td>0.083</td>
<td>1.158</td>
<td>0.2467</td>
</tr>
<tr>
<td>Ordinal * Age</td>
<td>0.007</td>
<td>-0.021 – 0.035</td>
<td>0.014</td>
<td>0.498</td>
<td>0.6182</td>
</tr>
<tr>
<td>Regularity * Age</td>
<td>-0.048</td>
<td>-0.151 – -0.054</td>
<td>0.052</td>
<td>-0.925</td>
<td>0.3548</td>
</tr>
<tr>
<td>Type * Age</td>
<td>-0.016</td>
<td>-0.122 – -0.089</td>
<td>0.054</td>
<td>-0.299</td>
<td>0.7647</td>
</tr>
</tbody>
</table>

The final model only reveals significant main effects of ordinal and regularity, such that higher ordinals are less likely to be comprehended correctly than lower ones, and that regular ordinals are much more likely
to elicit a correct response than irregular ones. These effects go in the expected direction. None of the other main or interaction effects are significant: we see no evidence for differences between synthetic (morphological, *fourth car* type) and analytic (syntactic, *car four* type) ordinals, beyond those determined by the regular nature of analytic ordinals, and there is no evidence for an effect of age.

Figure 5 depicts the percentage of correct responses per condition in the raw data. Note that cardinals, *first* and *last* are included here for comparative purposes, though we did not include them in the model.

![Figure 5: Percentage of correct responses to all tested ordinals and *last* in English. Error bars indicate 95% CI.](image)

Figure 5 shows that performance is consistent on most ordinals: both analytic ordinals and regular synthetic ordinals elicit relatively high scores (all hovering around 60%), though lower than cardinals, whereas correct responses to irregular (synthetic) ordinals *second*, *third* and *fifth* occur less than half of the time. The effect of this regularity is supported

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19 A reviewer asked for a more specific analysis looking only at *second*, *third* and *fifth* compared to their analytic counterparts. We ran another model on the subset of the data including only these ordinals, and ran a model identical to the first, minus the factor type and the accompanying interaction with age, as type and regularity are collapsed here. Formula: Response ~ OrdinalContinuous + Regularity + AgeInMonths + OrdinalContinuous: AgeInMonths + Regularity: AgeInMonths + (1 + OrdinalContinuous * Regularity | Subject) + (1 + AgeInMonths | Trial). Much like before, the only significant factor here is regularity ($\beta = 2.466, CI = 1.193 – 3.740, SE = 0.650, Z = 3.795, p = 0.00015$). There were no significant effects of ordinal ($p = 0.07$), age ($p = 0.2815$), or interactions between age and ordinal ($p = 0.4808$) or age and regularity ($p = 0.1329$).
by children’s semi-spontaneous production during the task: analytic forms hardly occurred, but a handful of children would sometimes produce regularized synthetic forms (*oneth, *twoth, *threeth and *five-eth), either during the task or in the counting session at the end. Forms such as *thirteenth did not occur. Like Dutch children, they would sometimes ask for clarification or indicate not knowing what to look for on the irregular trials, as the examples in (11) through (14) show. Such utterances did not occur on regular ordinal trials.

(11) Is fifth five?
(12) I don’t know which one the second duck is.
(13) Sometimes I don’t know what you’re saying, like with third.
(14) [Counts to six, was asked for fifth.] I think I passed it.

The figure also shows that the last and first objects in line (regardless of form) elicited the most correct responses: children responded correctly roughly 80% to 90% of the time. This is in line with the Dutch data above, and also unsurprising given the data and discussion in Chapter II and the acquisition of superlatives in general.

The figure presents group results. Individual patterns show that some children are more informative than others. Many exhibited consistent performance across the board, making them the least informative here. (Nine responded correctly on at least two out of three trials on each condition, while eight responded incorrectly on all conditions). However, six of the remaining children responded correctly to all regular ordinals, but made more than two errors per condition on all irregular ordinals. An additional two children knew all the regulars and second, one also knew third. Among the remaining ten children, no clear pattern exists for the regular ordinals. Four could find second but not third or fifth; whereas only one child could find third but not the other irregulars, or fifth but not the other irregulars. No children did worse on cardinal than ordinal conditions, no children did worse on analytic forms than synthetic ones, and no children only did well on (any) irregulars.

6.3 Discussion
The outcome above should now contain no real surprises, as it points largely in the same direction of the Dutch data, namely towards a rule-based approach to ordinal acquisition. The most telling piece of evidence
here is the presence of a significant effect of regularity, in the absence of
an effect of type. Analytic forms pose no additional problems to children,
despite their different form, slightly different meaning, and lower
frequency. Irregular forms, on the other hand, are more difficult than their
analytic counterparts and regular neighbors: performance on irregular
ordinals second, third, and fifth is lower than e.g., car three and the sixth
coat. We take this to be convincing evidence that a transparent
relationship between the ordinal and its cardinal base is most important
in acquiring ordinals. The few semi-spontaneous occurrences of oneth,
twooth, threeth and fiveth supports the idea that children have productive
knowledge of the ordinal formation rule. Such overgeneralizations have
been noted casually in the literature as well (Pinker 1999, Rumelhart &
Norman 1978).

The data also show that this transparency is not the only factor. The
effect of ordinal as a continuous variable suggests that the place in the
ordinal count list also plays a small but significant role. This encoding also
turned out to be a better way of describing our data than encoding ordinal
as a categorical variable. The effects of this factor are not as clearly visible
as in the Dutch data above: here, there is no clear drop in performance for
higher (regular) ordinals.\footnote{Note that an interaction between regularity and ordinal is not significant and does
not improve our model. Hence, this effect of ordinality holds across regular and
irregular forms.} Still, the difference between cardinal and
ordinal performance suggests that something about ordinals is
considerably more trying than cardinals.

Our data reveal no evidence for an effect of age in American English
speaking CP-knowers. This is unsurprising given previous work on Dutch,
which suggest that any age effect seems to be limited to the subset-knower
stages and plays a smaller role than knower-level, at least in
comprehension (cf. Chapter II and III). This makes it likely that, while of
course older children will do better than younger ones eventually, age does
not add anything above and beyond other predictors in our model, i.e., the
place of the ordinal in the count list and regularity. The lack of interaction
effects means this holds for all both synthetic and analytic, both regular
and irregular and low and high ordinals.

One further observation has to do with the performance within the
set of irregular ordinals. If any kind of transparency can help in acquiring
ordinals (not just the relationship between the cardinal and the ordinal),
then we might have expected *fifth* to elicit more correct responses: the irregularity here is not a case of suppletion (such as with *second*), but is ‘merely’ phonological, and only involves the vowel (and, depending on the speaker, devoicing or elision of the fricative).\(^{21}\) This is less complex than the relationship between *three* and *third*, which involves metathesis, a change in the vowel itself, and the suffix. This notwithstanding, performance on *fifth* is not better than on other irregular ordinals. Perhaps frequency and/or the factor ordinal outweigh any effect of the complexity of the irregularity, or perhaps the kind of irregularity is irrelevant — we leave this for future research to explore.

7. Comparison Dutch and English
The models presented for Dutch and English point in the same direction: the main factor of influence is regularity, not ordinal type. However, since the Dutch sample contained children in all of the five knower-level stages, it is hard to compare these results directly. We therefore conducted a third analysis, in which the CP-knowers from both languages are analyzed together. This not only keeps knower-level constant, but also means the groups are more comparable in terms of sample size (Dutch \(N = 41\), US English \(N = 35\)). There was no significant difference in age between the Dutch (\(M = 53.2, SD = 5.1\)) and English (\(M = 51.3, SD=7.0\)) groups (\(t(9.997) = -5.061, p < 0.0001\)).

In addition to the factors discussed for other analyses above (ordinal, regularity, type and age), we can now add in the effect of language as an additional fixed factor. Because previous models (in both languages, and in previous studies) did not provide evidence for interaction effects between age and other factors, we left them out of the present model.

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\(^{21}\) One might even argue that the alternation between /aɪ/ and /ɪ/ is a more general pattern found elsewhere in English, which might help children recognize the relationship between the cardinal and the ordinal. However, this alternation does not seem to correspond to a clear domain, word class, or semantic relationship; perhaps the most accessible case (besides the irregular plural of *child, children*) pertains to tense (e.g., *write–written, hide–hid*), but examples also include deverbal nouns (*crime–criminal, decide–decision, divine–divinity*) and adjectives (*apply–applicable, divide–divisible*), and derived nominals (e.g., *wise–wisdom, wide–width, rite–ritual*). The majority of these examples are unlikely to occur in child-directed speech. Even if the data were abundant in the input, the question remains whether this would lead to a broad phonological generalization. Children may be able to formulate a rule linked to tense, but our data suggest children cannot readily apply this rule outside the domain for which it was initially conceived.
Instead, we added in interactions between language and the other four fixed factors, to see to whether the patterns between the two language groups differed. We included by-subject random intercepts with slopes for ordinal (place in the count list) as a continuous factor and ordinal type (synthetic, e.g., *vierde auto* ‘fourth car’, or analytic, e.g., *auto vier* ‘car four’) and their interaction, and by-trial random intercepts with slopes for age (in months) and language. Table 5 describes the outcome of this model.

Table 5: Result summary for correct responses on ordinals in Dutch and English CP-knowers: \( \beta \) coefficient estimates, confidence intervals, standard errors, associated Wald’s \( z \)-score and significance level \( (p) \) for all predictors. Formula: 
Response \( \sim (\text{OrdinalContinuous} + \text{Regularity})\text{Language} + \text{Type} + \text{AgeInMonths} + \text{Type:Language} + \text{AgeInMonths:Language} + (1 + \text{OrdinalContinuous}ynth*\text{Type}|\text{Subject}) + (1 + \text{AgeInMonths} + \text{Language}|\text{Trial}). \)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimate</th>
<th>CI</th>
<th>SE ( \beta )</th>
<th>( z )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.787</td>
<td>0.069 – 1.505</td>
<td>0.366</td>
<td>2.149</td>
<td>0.0316</td>
</tr>
<tr>
<td>Ordinal</td>
<td>-0.303</td>
<td>-0.410 – -0.196</td>
<td>0.055</td>
<td>-5.531</td>
<td>(&lt;0.0001)</td>
</tr>
<tr>
<td>Regularity</td>
<td>1.833</td>
<td>1.368 – 2.298</td>
<td>0.237</td>
<td>7.728</td>
<td>(&lt;0.0001)</td>
</tr>
<tr>
<td>Language</td>
<td>-1.755</td>
<td>-3.187 – -0.324</td>
<td>0.731</td>
<td>-2.403</td>
<td>0.0163</td>
</tr>
<tr>
<td>Type</td>
<td>-0.347</td>
<td>-0.845 – 0.153</td>
<td>0.255</td>
<td>-1.361</td>
<td>0.1735</td>
</tr>
<tr>
<td>Age in months</td>
<td>0.121</td>
<td>0.005 – 0.238</td>
<td>0.059</td>
<td>2.047</td>
<td>0.0406</td>
</tr>
<tr>
<td>Ordinal * Language</td>
<td>0.153</td>
<td>-0.060 – 0.366</td>
<td>0.109</td>
<td>1.41</td>
<td>0.1585</td>
</tr>
<tr>
<td>Regularity * Language</td>
<td>0.833</td>
<td>-0.070 – 1.737</td>
<td>0.461</td>
<td>1.807</td>
<td>0.0707</td>
</tr>
<tr>
<td>Language</td>
<td>0.554</td>
<td>-0.44 – 1.549</td>
<td>0.508</td>
<td>1.09</td>
<td>0.2758</td>
</tr>
<tr>
<td>Type</td>
<td>-0.094</td>
<td>-0.322 – 0.134</td>
<td>0.116</td>
<td>-0.805</td>
<td>0.4211</td>
</tr>
</tbody>
</table>

The model reveals significant effects of ordinal, regularity, language, and age. None of the interactions are found to be significant, though the interaction between regularity and language trends towards significance, such that the effect of regularity is greater for English-speaking CP-knowers (see also Figure 6).  

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22 A reviewer points out that our comparison may have had a different outcome if we had considered a different definition of regularity, e.g., had coded *fifth* or *achtste* as regular. While this is true, the descriptive data in Figure 5 and the outcome described for Dutch in section 5 lead us to believe the distinction we hypothesized suits the
Effects of ordinal and regularity are of no surprise at this point, nor is the lack an effect of ordinal type: for both languages, we saw that higher ordinals yielded lower comprehension scores than lower ones, as did irregular forms compared to regular ones, and that children do not experience greater difficulty with *car four* type (analytic) ordinals over *fourth car* type (synthetic) ones. Again, we take this all to point in the direction of rule-based learning, with only a small part of the pattern related to age. The main purpose of this extra model, however, was to examine any effects of language. These effects turn out to be significant: the English learners are less likely to provide a correct response than Dutch learners.

Figure 6: Mean percentage of correct responses on all definite ordinals tested, for irregular and regular ordinals for both Dutch and English CP-knowers. Error bars indicate 95% CI.

Figure 6 shows the mean percentage of correct responses to Dutch and English ordinals, grouped by the (ir)regularity of the tested ordinal. (See sections 5.2 and 6.2 for individual ordinal results per language.) While Dutch children outperform the English learners when it comes to regular ordinals, the clear difference is in the irregular domain: Dutch CP-knowers provide more correct responses to *derde* ’third’ than English learners to *second, third, and fifth* combined. English does have more irregular ordinals than Dutch, and so English learners are presented with a greater challenge as they have more exceptions to acquire. It also means they have less evidence for the regular forms, which we think leads to a marginal general delay in ordinal acquisition. Ultimately, however, having less present purposes and that a different categorization would not be more valid or informative.
evidence for the rule does not impact their ability to acquire the rule, only the amount of time they need to do so. The English group shows that they have sufficient evidence for a productive ordinal formation rule, and that, as in Dutch, a rule-based acquisition pattern is favored over lexical learning.

8. Conclusion
The data from our two ‘Give Me’-type comprehension experiments are clear: regularity is key. As long as the relationship between an ordinal and its cardinal base is transparent, children are able to derive the meaning of the ordinal, regardless of whether the ordinal is ungrammatical and absent from the input (as with *driede ‘three-th’), and regardless of whether it is formed syntactically (as with analytic ordinals such as auto drie ‘car three’) or morphologically (as with the more naturally occurring vierde auto ‘fourth car’). Though the ordinals that we considered irregular here differ with regard to what makes them irregular (second, third, fifth and derde ‘third’ are all ‘irregular’ in a different way), for the learner this does not seem to matter much: the cardinal root must remain untouched. We leave effects of irregularity type to be explored in future work.

The generalization above not only holds for learners of Dutch, a language with a relatively regular ordinal count list, but also for learners of English, which has a much less regular ordinal list and thus provides less evidence for the ordinal rule. However, the pattern they exhibit differs: while Dutch learners show a clear effect of ‘low’ ordinals (≤4) and ‘high’ ones (≥6), the effect of place in the ordinal list is more gradual in English. We suggest this difference between Dutch and English is caused by what cognitive processes play a role and what evidence is needed. For lower ordinals in Dutch, children have sufficient evidence for the ordinal rule within the OTS domain. For higher ordinals, ANS and OTS must be co-activated. This extra component adds to the cognitive load, which prevents successful application of the rule until that added difficulty is overcome. (Alternatively, the learner may initially think the rule applies only to low ordinals, failing to process evidence from high ordinals as evidence for the same rule.) The data in Chapter III suggest this happens by age 5, some six months after Dutch children typically become CP-knowers.

This difference does not appear in English because there is insufficient evidence for a rule within the OTS domain: fourth conforms to
a rule that the learner can only postulate if he has collected evidence from higher ordinals such as *sixth* and *seventh*. Put differently, merging OTS and ANS is necessary for English learners to comprehend any ordinals. This may require a longer learning trajectory. Though the English learners in our sample were the same age as the Dutch children we tested, the literature would suggest they have been CP-knowers for longer, allowing them more time to actively train their ‘number muscle’, while they collect the relatively scarce evidence needed for the ordinal rule. Note that the rule-based approach is nonetheless the more efficient option. If it were not, we would have expected earlier acquisition of the most frequent forms (e.g., *second*). A lexicalist approach cannot account for the difficulties with irregular forms, the relative ease of analytic forms, or the individual responses described above — neither for the Dutch, nor for the English data. Instead, it seems that regularity, or at least a transparent relationship between the cardinal and the root, is key.

These findings therefore support the main hypothesis under investigation in this paper, and are in line with previous work, but also fails to resemble acquisition patterns typically described for the acquisition of derivation (as discussed above, in Chapter III and Clark 2014) or inflection (see Chapter III). However, as Clark (2014) notes, the acquisition of derivation relies on children’s ability to identify the components of complex words, the semantic transparency of the affix and frequency. Ordinals may not be frequent, but their formation is reliable and transparent; the rule is productive in a machine-like fashion for any cardinal root. And cardinals, being somewhere between adjectives and nouns (Corbett 1978), are something of a linguistic outcast in themselves. Given that they stand out, and are notoriously cumbersome to learn, perhaps we should not be surprised if children are alerted to cardinals and are eager to recycle numerical knowledge they already worked so hard to acquire the first time. The contribution of the ordinal affix is relatively easy once the meaning of the cardinal is clear, and so linguistically the (regular) ordinal is no challenge. The real hurdle is getting the underlying concepts in place and maintaining the integration between two abstract systems of number (OTS and ANS); the morphological irregularities follow soon enough.
Chapter V

Discussion

1. In a nutshell

Whether you have read all of the chapters above and thus finally made it to the discussion, or have strategically flipped through to this page, you should know that this dissertation is about how children acquire different kinds of numerals, most especially ordinal numerals (such as in the fifth chapter or chapter five). You should also know that the main finding put forward here is that children acquire irregular ordinal numerals (such as Dutch derde ‘third’ or English second) after regular ones (such as vierde ‘fourth’ and seventh), and also after analytic ordinal forms like pagina drie ‘page three’. I account for this by arguing that children use morphological structure in the acquisition process, leading them to first acquire the ordinal forms that follow a rule (informally: cardinal + suffix = ordinal, or for the analytic cases: cardinal numeral after the noun = ordinal), before acquiring exceptions like second and third later on. This rule-based pattern and approach holds for Dutch and English, and for comprehension as well as production. The cardinal acquisition pattern, on the other hand, looks nothing like this: not only does cardinal acquisition begin at a younger age, it also follows a sequential pattern, in which the first numerals in the list are acquired one by one (rather than nearly all at once).

Throughout the course of this work, I have argued that this outcome should not be taken for granted; as intuitive as it might seem at first sight, the acquisition pattern I just described was certainly not the only possible one, and is certainly not without its questions. This notwithstanding, I maintain that the analysis put forward here is the only reasonable one given the data at hand. As a result, I want to start this chapter by making sure there is no confusion about the answers to the four initial questions put forward in Chapter I, repeated here in (i) through (iv).

(i) Does the pattern and timing of ordinal acquisition differ from that of cardinals, and if so, can these differences be related to linguistic factors? (Chapter II)
(ii) How does the development of ordinal production compare to the development of ordinal comprehension, and do children generalize an ordinal formation rule? (Chapter III)

(iii) Are strictly rule-based ordinals always comprehended before more frequently and normally used irregular forms, even if those rule-based forms are ungrammatical, infrequent or limited to certain contexts? (Chapters III and IV)

(iv) Does ordinal acquisition follow a rule-based pattern in English, and how does the English pattern compare to Dutch? (Chapter IV)

Sections 2 and 3 answer these questions, ending with a summary of the stages in ordinal acquisition. Section 4 then addresses the 'why'-question for the attested patterns, which I have not been able to address properly anywhere else.

2. Dutch cardinals are like other cardinals
The first research question is whether the pattern and timing of ordinal acquisition differs from that of cardinals, and if so, whether those differences can be related to linguistic factors. The most explicit part of this comparison is dealt with in Chapter II, where the stages for both numeral types are fleshed out in detail. With each additional study (discussed in Chapters III and IV), though, it became more clear to me how different cardinal and ordinal acquisition really are.

Before getting into that, let me first address a side question in Chapter II, namely whether the pattern found for Dutch cardinals aligns with the robust pattern attested for various languages and cultures discussed in the literature. Unsurprisingly, it does. Dutch children acquire cardinals in the same way other children do: one cardinal at a time, following the order in the count list, until at some point they are able to generalize their knowledge over an entire count list. Acquiring cardinals is universally slow and arduous, and requires complex pieces of (linguistic and non-linguistic) knowledge to fall into place. The child needs to master at least three of Gelman & Gallistel's (1978) counting principles: the one-to-one correspondence principle (every cardinal belongs to one item, object, sound et cetera), the stable order principle (the count list has a strict order), and the cardinality principle (the numerosity of the set is equal to the last number counted), all while figuring out that cardinals refer to an exact quantity (and which ones).
This buildup of knowledge is reflected in the acquisition pattern, as individual cardinals are pieced together before making the appropriate conceptual leap. The pre-knower stage is the first step, and entails some basic understanding of what it means to be a number and what it means to count. Pre-knowers recognize that cardinals refer to numerosities (even though they do not know exactly which) and that there is such a thing as a counting routine. They can ‘count’ (i.e., recite numerals) to some extent, though not productively (as an answer to how many) and they might not recite the numerals in the right order for quite some time.

In order to say that a child has acquired a cardinal in the subsequent stages (i.e., from one-knowers through four-knowers), that child must be able to give you that quantity when asked for it: a two-knower can pack two puzzles in a toy suitcase. Crucially, a two-knower also knows that other numerals are not two. Lower cardinals that the child knows have exact meanings (being a four-knower also implies being a three-knower, a two-knower, et cetera) and higher cardinals that the child (thus) does not know, must refer to more. In other words, when asked for three hats, the two-knower may return with three hats, but more or less by chance — he might also bring four, five, or even more, but not two, and when asked for one toothbrush, he knows to get exactly one. Subset-knowers typically do not count (or do not follow the appropriate principles) to determine their responses. Children in the pre-through-four-knower stages are referred to as ‘subset-knowers’, as they know a subset of the numerals in their count list.

As mentioned repeatedly, the start and duration of each stage varies considerably, both between studies and between individuals. The literature reports children generally moving through the cardinal acquisition stages somewhere between the ages of two and four, and the work I present here reveals that Dutch children acquire ordinals in a slow, sequential fashion, too. Figure 1 shows the distribution of knower-levels across age groups for all the Dutch children I tested combined.

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1This is not the same as the ages at which ordinals are acquired, as I only have data that reflects the stage in which these children were at the time of testing, not how long they were in that stage. This is especially noteworthy for CP-knowers, who may well have been in competent counters for some time.
The summarized data above show that Dutch children’s acquisition of cardinals also varies: while many children are competent counters by the age of 3;6, some five-year-olds are still in the process of fully understanding cardinality. Most fall within the age range listed above, but the observant reader might point out that the Dutch children as a group seem to be somewhat (roughly six months) slower than their peers in some other parts of the world.

In fact, Chapter IV shows that though the US English-speaking children tested do not differ significantly in age from the Dutch children in the same chapter, they do differ in terms of cardinal knowledge: the Dutch sample shows a full range of knower-levels, whereas all but one of the English speakers are CP-knowers. This could be completely coincidental (as I state in Chapter IV, section 6.1), or perhaps an effect of sampling. I think it is more likely this is related to a plethora of potential other factors, some of which I discuss in Chapter II, section 5.1. I did not carry out additional measures to explore effects of SES or general vocabulary size (Chapter II, footnote 8), for example. I also did not look into effects of number talk, so to what extent parents discussed quantities or practiced counting and labeling sets in their day-to-day interactions with children. Obviously, (pre)schools are also places where number talk may occur. Though I did not investigate whether Dutch children are systematically behind in these domains, such factors may at least explain some of the individual variation (cf. Lidz & Gagliardi 2015 for discussion of the role of SES and input on vocabulary development; Gunderson & Levine 2011 and Negen & Sarnecka 2012 for effects of input on cardinal development). I do not think this Dutch delay is related to anything inherent to the specific language being learned — qualitatively, their behavior aligns neatly with the patterns reported in the literature, and we will see it does not affect their ordinal learning.
3. Ordinals are not like cardinals

Now that we know what, how and when cardinals are acquired (what it means to ‘know’ a cardinal, what knowledge different stages represent, and when this knowledge is acquired) we can ask how this differs from the timing and pattern of ordinals and whether linguistic factors play a role.

The quick answer: ordinals are acquired after cardinals and in a very different way. These differences can be linked to linguistic properties of the ordinals being acquired.

The findings in Chapter II show that something different is going on in the ordinal case, despite the fact that cardinals and ordinals are conceptually related. The most important of these findings is that ordinals are not acquired neatly in order: irregular derde ‘third’ is not acquired third, just after eerste ‘first’ and tweede ‘second’, but arguably after all the other ordinals I tested, like negende ‘ninth’. Children scored equally high on regular, rule-base forms such as tweede ‘second, lit: two–th’ and vierde ‘fourth’, and lower on irregular derde ‘third’, which suggests regular synthetic ordinals are not acquired individually, but at roughly the same time. Moreover, the timing of this knowledge of rule-based forms was striking: children acquire regular ordinals right around the same time children grasp cardinality, leading to a pattern in which the all-at-once part of ordinal acquisition happens first, and some individual numerals (the irregular ones) follow later. Put differently, the conceptual leap is the start of ordinal comprehension and production, not the end of it. Quite the opposite from the cardinal case.

As eventually discussed in Chapter IV, this pattern needed to be modified somewhat, but it did lay the ground for the working hypothesis that I set out to explore in the rest of this book. Perhaps contrary to what one could have reasoned on the basis of cardinal development, the data led to questions that had little to do with cardinals or core knowledge, and everything to do with linguistic structure: what if ordinals were acquired via a rule (informally: cardinal + ordinal suffix = ordinal)? What if children were to use the morphological structure to grasp the meaning of ordinals, taking knowledge of the parts (the cardinal root and the suffix) to acquire the whole? Chapters III and IV go into the obvious questions that follow from that idea, investigating to what extent there is evidence for rule-based learning, both in the places we expect it and in the way that we expect it. Put differently, do we find evidence for rules in production, in other ordinal types, and in other languages? I can be brief: yes, yes, and yes.
3.1 Overgeneralizations

Chapter III delves into the first of those sub questions, asking how the development of ordinal production compares to the development of ordinal comprehension, and whether children generalize an ordinal formation rule. Children are known for using rules a little overzealously, overgeneralizing past tense –ed to form *eated and *goed, and plural –s to make *tooths rather than teeth (e.g., Marcus, Pinker, Ullman, Hollander, Rosen & Xu 1992; Pinker 1999). If children use a rule to acquire ordinals, then one prediction is that children would produce the ungrammatical yet regular form *driede ‘threeth’ (using the regular cardinal root) rather than derde ‘third’, for which the link with the underlying cardinal is more opaque. This prediction is borne out. Dutch children say *driede, both those who can find the derde ‘third’ in a comprehension test, as well as those who cannot, suggesting that transparency is key (the transparent form is easier despite its ungrammaticality) and that production takes longer than comprehension.

This overgeneralization works both ways, as the evidence shows it also decomposes into comprehension: when asked to find the *driede ‘threeth’, children who could find other regular ordinals (such as vierde ‘fourth’) had no difficulty picking out the third item in line. This even applied to children who could not find the derde ‘third’, again showing transparency matters. *Driede may be ungrammatical, but it is nonetheless derivable and thus interpretable, whereas the irregularity of derde gets in the way. When children ask Wat is der? ‘what is thir?’ or, better yet, Hoeveel is der? ‘how many is thir?’, this is a clear sign children do not have difficulty with the ordinal suffix, but are struggling with the root allomorphy involved and do not see der as a variant of drie. The rule for ordinal formation is in place before the exceptions are.

That last line should surprise you if you were nodding along when I mentioned *eated, because unlike *eated, ordinals like *driede are not preceded by an initial stage in which children do use the appropriate form. Children may lapse into a phase where regularized forms are used instead of or in tandem with ate and went, but the data provide no evidence for such a U-curve for derde (or, to a lesser extent, for irregular ordinals in English). It would make no sense for children who say *eated to suddenly stop understanding what ate means, and this is especially true given that they typically do not stop producing ate altogether. Thus, when children fail to find the derde ‘third’ when they can find the *driede ‘three–th’ and the zesde ‘sixth’, we should not assume that derde ‘third’ was temporarily
lost in translating individual forms into rules. Instead, we should assume that children use the rule to begin understanding ordinals. (See the last section of this chapter.) Incidentally, that is also one of the things that makes the rule exciting — **of course adults ultimately wind up with a rule, but how obvious is it that children would start out with one?** The fact that U-curves or ‘change for the worse’ patterns exist in child language already suggests the answer is *not very.*

### 3.2 Rules rule

The question is how important that rule or transparency is. It is one thing to say that a transparent relationship with a cardinal helps to understand an ordinal, but it is quite another to say that children use that structure to actually acquire meaning, that they compute or derive the meaning of an ordinal by actively dissecting its parts. Regular forms need not always be useful to learners, and it is reasonable to wonder whether other properties of the ordinal also play a role, such as its frequency or the way it is used. Of course, the fact that *derde* ‘third’ is more frequent than the regular ordinals that follow it (see Chapter II) and yet is acquired later, should tell us that (token) frequency is not the star of this show. Still, it raises the question whether any kind of regularly constructed ordinal could be ‘in place’ before exceptions like *derde* ‘third’. Or, as formulated in Chapters III and IV, are strictly rule-based ordinals always comprehended before more frequently and normally used irregular forms, even if those rule-based forms are ungrammatical, infrequent or limited to certain contexts?

The **strictly rule-based** ordinals I am referring to here are ordinals such as *chapter five* or *participant 6*. Such low-frequent ordinals are also known as analytic ordinals or syntactic ordinals, and differ from synthetic (vierde auto ‘fourth car’) ordinals in various ways, as I discuss in Chapter IV. For one, there are clear structural differences leading to a reversal in the order of the numeral and the noun and the absence of both a suffix and a definite determiner. Such ordinals do not readily resemble frequently used forms, although they are not absent from the input. For another, they are not as universally acceptable in all the contexts synthetic ordinals are — *please read chapter five, sure, but go left at traffic light three?* I would say that only works if the traffic lights had been listed or labeled explicitly before, as if it were a name. That makes their use rather restricted, and their semantics perhaps somewhat different (see Wiese 2003 on nominal
cardinal constructions). In terms of frequency, form, and use these analytic ordinals could be seen as tricky for the learner who relies on those types of information, but for the learner focused on transparency they should be a piece of cake.

This, too, turns out to be the case. I tested this in both Dutch and US English learners and found no significant difference between regular synthetic ordinals and analytic ones, though there is a significant effect of regularity. Analytic ordinals for the third in line (auto drie and car three, respectively) elicit more correct responses than their irregular synthetic counterparts (de derde auto and the third car, respectively), and something similar holds for the other irregular ordinals in English. Moreover, the difference was visible in children’s behavior as well. Whereas irregular ordinals sparked questions and comments from child participants, cow five and raket zes ‘rocket 6’ prompted recounting at worse; reliable counters found the appropriate items quite swiftly and confidently. Much like the ungrammatical *driede ‘threeth’, these ordinals are not likely to have been learned by rote, making children’s success on these items a clear case of computation rather than storage.

A valid question at this point is to what extent we are dealing with actual acquisition of anything and whether it could be the case that children were just using syntax as some kind of strategy. In other words, could we claim that the children who participated in the study did not actually ‘know’ these ordinals but just figured out a nifty trick that worked in the context of the experiment? And could it be that precisely because children were undeterred by the weirdness of analytic ordinals, they probably did not have a full understanding of their meaning? I guess it is possible to carry out additional experiments to explore how children use and understand different ordinal types in different contexts — CHILDES will not get us very far — but my initial response is that this ingenious use of the structure underlines my point rather than argues against it: structure is easy, meaning is hard, and children use the former to get to the latter.

If children did not care about the form, they would simply learn derde ‘third’ by rote (as they initially do with low cardinals). If syntactic structure were hard, they would fail on analytic ordinals because they would have nothing else to guide them. Yet children easily decompose the structure to find an interpretation that works, even if it involves movement and unconventional word order (with a numeral following the noun rather than preceding it). If they can figure out how to get from car
three to find the third car (apply the appropriate counting principles and deduce that the appropriate reading is an ordinal one rather than a cardinal one) on-the-spot during testing, why would they do something else in their everyday language challenges? The strategy must come from somewhere.

Using syntax to get to semantics is not a new idea that applies to ordinals only — various studies show that children can use syntactic information to learn the meaning of novel verbs or (i.a. Gleitman 1990; see Lidz & Perkins 2017 for a recent overview) or superlatives for example (Wellwood, Gagliardi & Lidz 2016). Even within ordinals, the strategy is quite general, rather than specific, which in turn suggests that children do not use the synthetic ordinal form (the morphological rule) alone to acquire ordinality. The precise form of the ordinal rule is not the guiding principle. Ordinal meaning can be achieved by attaching a suffix to a cardinal or raising the noun to some higher position (the exact analysis of analytic forms is not important here), as long as the child can recognize the cardinal base and recognize that the form as a whole differs from just the cardinal. I return to this later; first I want to put a little more pressure on the importance of this transparency, by looking at what happens in a language in which this is less abundant: English.

3.3 English
The similarities between English and Dutch go beyond performance on analytic ordinals, which is critical to the central argument in this book. To claim that Dutch learners acquire ordinals via a rule (or irregular forms later) could seem trivial, since *derde* ‘third’ is the only true exception in the ordinal count list (putting aside *eerste* ‘first’ for now). It makes the rule salient and perhaps it is easy to overlook an irregular form like *derde* ‘third’ in such a language. If this sounds unconvincing, look at it from the English learner’s perspective: if a child has many exceptions to acquire, and these exceptions are all at the beginning of her count list and are, not coincidentally, also more frequent than rule-based forms (such as *ninth*), then perhaps he is not interested in a rule. He might consider the rote-route to ordinals more economical in this case — that is even assuming that he has enough reason to consider the existence of the rule to begin with. After all, more irregular forms means less evidence for rules. That does not preclude the rule-based pattern, but might delay it, because collecting sufficient relevant evidence could take more time.
Because English is (from this perspective) such an unattractive language for the ordinal rule learner (with exceptions second, third, and fifth), Chapter IV set out to discover whether children acquiring English follow the same strategy as Dutch learners do. And again, the answer is yes. English-speaking children follow a rule-based pattern, too. They comprehend regular ordinals more often than irregular ones, which leads to a different superficial pattern from the Dutch case, (regular tweede ‘second, lit ‘two–th’ elicits more correct responses than English second) but the general pattern is the same. English learners also make overgeneralization errors, producing *two–th, *three–th or even *five–eth during the task. Such overgeneralizations have been noted casually in the literature, as well (Pinker 1999, Rumelhart & Norman 1978).

One noteworthy similarity is the observation that Dutch ordinal acquisition is not behind that of English speakers, despite the finding that Dutch learners are typically slow to acquire cardinals. In fact, the Dutch children outperformed the English learners, especially on the irregular conditions. You might want to say that means the Dutch learners catch up, and that the acquisition of ordinals is not time-linked to the acquisition of cardinals. But then what is it linked to? Is it some effect of maturation? The statistical analyses I ran came up with mixed results for effects of age, though of course it is obvious that children know more as they get older. Further research should try to provide more insight in what needs to mature in CP-knowers before they can acquire ordinals, but here I want to focus on an alternative explanation: all the irregularities make the English ordinal system more complex to acquire, and the evidence for the ordinal rule more sparse. And apparently, English learners are willing to take the time processing that input, giving the Dutch time to acquire cardinals and catch up. Regularity outweighs rote-learning in both groups.

This waiting does lead to a more fundamental difference between Dutch and English learners, which is that while English-speaking children do show roughly equal performance on regular ordinals, some Dutch children exhibit better performance on ‘low’ ordinals (tweedde ‘second’ and vierde ‘fourth’) than high ordinals (I tested zesde ‘sixth’, achtste ‘eighth’ and negende ‘ninth’). At first glance, this does not seem to mesh well with a rule-based approach. After all, if children have a rule, they should be able to apply it to all the cardinals in their count list. This is in fact exactly what I argued just a few pages ago, because it is the prediction that you make.
But we should be careful not to throw the baby out with the bathwater: the rule-based prediction does explain the English data, it does explain the difficulties with derde ‘third’ and the overgeneralizations in production with achtsste ‘eighth’, and the Dutch children in Chapter III do follow the prediction the rule-based approach makes. I therefore think it is likely that something else is meddling with children’s behavior in Chapters II and IV. I speculated in Chapter II that it might have to do with performance, i.e., that children are let down by their motor skills, attention spans, working memory or anything involved in keeping count as the count list progresses. This may also play a limited role, but the data in Chapter IV suggest a better explanation can be found if we go back to cardinals and the core of number learning, and consider that the distinction between low and high ordinals bears the hallmark of the core knowledge systems of number.

Children acquiring cardinals do so slowly, until they suddenly overcome the boundary that distinguishes four-knowers from CP-knowers. Children who know the cardinal principle are successfully able to integrate the Object Tracking System (OTS), useful for keeping track of up to four items, and the Approximate Number System, which is better suited for larger (though inexact) quantities (see Chapters I and II). CP-knowers combine these systems in order to conceive of large, exact quantities and know the exact meaning of numerals in their count list, but that does not necessarily mean that these systems are permanently combined.

Therefore, though I did not test vijfde ‘fifth’, I think the difference between low and high ordinal performance in Dutch is related to integrating OTS and ANS, and I think it does not arise in English children because of the data children have to consider in order to acquire the rule that, in turn, helps them acquire ordinals. Put simply, the hypothesis is that though CP-knowers have the capacity to combine ANS and OTS, integrating these systems in addition to processing ordinal morphology is temporarily too taxing for young children. They can, for some period of time, either combine numerical systems, or combine OTS with the ordinal affix, but not both. (Note that the ANS is not a suitable domain for ordinal processing, as definite ordinals inherently require individuation, referring to exact individuals.) Within the OTS boundaries, Dutch children are able to collect sufficient evidence from regular tweede ‘second’ and vierde ‘fourth’ for an ordinal formation rule, whereas English learners are not (see Chapter IV and Yang 2016 for discussion on what constitutes sufficient evidence). The evidence they
need can only come from higher ordinals, as the beginning of the ordinal list comprises mostly irregular ordinals (or only irregulars, since fourth is only regular in the company of e.g., sixth, seventh, et cetera). As a result, I suggest that English learners must be accomplished ANS-OTS integrators in order to acquire the rule, whereas Dutch learners (and learners of languages with more regular ordinals, such as German or Chinese) can start a little earlier on. Again, this hypothesis relies on the assumption that the ANS and OTS are not for once and for always combined when the child becomes a CP-knower, but remain two separate systems that need to be co-activated, applied in tandem, whenever larger exact quantities are at play.

In a sense this makes acquiring ordinals like learning how to drive a car with a manual transmission. In order to get the car to move, or to be able to shift gears, you need to get releasing and engaging the clutch just right (in addition to doing countless other things at the same time, such as steering, monitoring traffic, et cetera). If you succeed in getting the transmission to adapt the output of the engine to the drive wheels, they will roll and you will find yourself in control of a moving vehicle. If you fail, however, there is no control, and you will not get very far: the engine might rev but the car will not move, or the car might buck uncomfortably a couple of yards, and/or the engine will stall. You could also just stay in one gear, of course, but there are not many situations where this would be appropriate. Thus, to finish the analogy: English learners are experienced drivers who have automatized the process, whereas Dutch children are in the numerical parking lot learning how to use the clutch. The difference is six months of CP-knowerhood. While Dutch children are busy acquiring cardinals, English learners are busy strengthening their numerical foundation and accumulating ordinal evidence; the evidence only becomes useable or interpretable once the numerical foundation is solid enough.

Of course, this still leaves the question why English learners ‘wait’ for the ordinal rule, rather than acquiring lower ordinals lexically. I return to this in section 4. It also raises questions for future research, which could explore to what extent an OTS effect is and is not visible in other languages. The prediction is that this is and must be visible in languages with sufficient evidence for an ordinal rule within the OTS boundary, but not visible in languages where there is not, unless the learner (in my view unexpectedly) resorts to lexical learning. In that sense, it would be interesting to look at analytic ordinals in younger English CP-knowers, to see if we do see this effect in analytic ordinals (rocket six).
3.4 Other findings

The findings I discuss in the sections above are the most critical to the main questions put forward in this work. However, for those who know Dutch, or for those who have committed themselves to reading the whole book, it should be clear that I have skipped some complicating factors that ultimately boil down to the question of what I have considered an irregular ordinal. For example, this chapter has yet to mention anything about eerste ‘first’; isn’t this an irregular ordinal, too? In addition, Dutch has two ordinal suffixes in its inventory (–de for most ordinals under twenty and –ste for all other ordinals), and should one of them not be considered an exception?

I can be brief about eerste and first. I follow Barbiers (2007) in taking these forms to be superlative adjectives rather than ordinals (see e.g., Chapter II). The results support a different theoretical take on eerste than other ordinals, as they show that these forms are acquired earlier than regular ordinals like tweede ‘second’ and fourth. Chapter II puts forward some data on superlative comprehension, Chapter III discusses some noteworthy observations in production, and Chapters III and IV also compare middelste ‘middle–st’ and laatste, last and suggest that eerste is indeed more like those superlatives than the tested ordinals.

For all other ordinals, the data and I agree that for the children I tested, irregular is basically any ordinal that is not analytic and does not immediately and straightforwardly follow from adding a suffix to a cardinal base. Whether the irregularity is merely phonologically driven, a case of root allomorphy, or a case of suppletion, second, third, fifth and derde ‘third’ are all equally irregular in my analysis. While you might feel I am painting with a broad brush, I would say there was no other reasonable option: each type of irregularity occurs only once, immediately confounding the type of irregularity with at least the place of the numeral in the count list and the frequency of that numeral. I did try to look at effects of individual ordinals by attempting linear mixed models in which the ordinal was a categorical variable, but to the extent that these models converged they did not explain more than looking at regularity in general terms. I think this issue is inherent to the phenomenon.

I have considered achtste ‘eighth’ irregular, too, at least for the statistical analyses. This choice is debatable. It could be argued that ordinals ending in –ste are actually the default, since –ste enjoys a greater type frequency (occurs on more individual ordinals) and attaches to more roots when taking the infinite number of numerals into consideration.
However, most ordinals children hear are likely to be ordinals negentiende ‘nineteenth’ and under, which (besides achtste ‘eighth’) all take –de. Chapter III shows that most children take –de to be the default, too, producing *achtde instead of the adult form. Some overgeneralize –ste, but by far the most of them do so on the ordinal for ninth only, saying *negenste rather than negende. From a production perspective, achtste is irregular, though it differs from derde ‘third’ in that in is much less of a challenge in comprehension.

3.5 Stages in ordinal acquisition
The patterns and tendencies summed up above can be translated to a series of stages in acquisition. The overview in (1) is a fine-tuned version of what is listed in Chapters III and IV, and could be taken as the hypothesized acquisition pathway for all languages.

(1) Stages in ordinal acquisition

(i) Children use morphosyntactic cues (such as the fact that ordinals combine with singular nouns whereas most cardinals combine with plurals) to discover that ordinals refer to individuals, not sets. They can give you one item when asked for e.g., the vierde ‘the fourth’, but it might be the second or the ninth in line.

(ii) Children, when they are at least four-knowers, acquire eerste ‘first’ first. This form is acquired relatively early for three reasons. It does not require true counting competence, it is roughly 50% more frequent than tweede ‘second’ through twintigste ‘twentieth’ combined, and it has been shown to be a regular superlative (of eer ‘(be)fore’, rather than an ordinal derived from cardinal één ‘one’) in Dutch (Barbiers 2007), which are acquired early (cf. Syrett 2016). Something similar holds for English.

(iii) Children subsequently acquire the ordinal formation rule (informally: cardinal + suffix = ordinal). Children in this stage can reliably find at least low, regular ordinals if the lower ordinals provide sufficient evidence for the rule, such as in Dutch tweede ‘second, lit: two–th’ and vierde ‘fourth’. If higher ordinals are needed for the generalization, CP-knowers should comprehend both lower (≤4) and higher (>5) regular ordinals.
(iv) Performance on higher, regular ordinals is (by definition) limited to CP-knowers only, since children who cannot count beyond *four* cannot be expected to count to higher ordinals either. CP-knowers may have difficulty with higher ordinals due to task demands (the further one has to count and maintain one-to-one correspondence, the more demanding the task becomes) but also due to the extra challenge of combining the two core number systems (OTS and ANS) with the ordinal formation rule. For lower ordinals, the ANS need not be recruited, but for higher ordinals, both systems are necessary.

(v) Performance on irregular forms (such as *derde* ‘third’ in comprehension and production, and *achtste* ‘eighth’ in production) follows at some point after acquisition of the rule. Note that this might be before or after performance on higher ordinals improves.

In summary, the chapters above present data from a total of 250 children (aged 2;08–6;04) who participated in one of four experiments. These experiments all look at ordinal acquisition from a slightly different perspective, but all consistently lead us to the same conclusion and allow us to paint a fairly clear picture of how ordinals are acquired: by means of a rule.

### 4. But why?

Perhaps the most urgent question now is how this rule learning works, or where the rule ‘comes from’. At various points above, I compared ordinal acquisition to the typical pattern for e.g., the past tense rule, but I have not made explicit why ordinals are so difficult to understand in this light and why the ordinal pattern looks the way it does.

To my knowledge, accounts that assume morphological productivity in children all assume that storage precedes computation (cf. Don 2014; Pinker 1999; Yang 2016; Lignos & Yang 2016 for discussion of these and other accounts). That means that under a dual-route, words and rules, or words and competition type approach, children store forms such as *washed, dressed, brushed, cleaned* and so forth as morphologically simplex forms in the mental lexicon, paired with their counterparts *wash, dress,* etcetera. At some point, the child is able to decompose the past tense forms into verbal stems and the past tense morpheme, which then gets stored as a separate entry from the stem. The child keeps track of the combinations of form and meaning lexically, and when the positive evidence reaches the
necessary threshold, the child generalizes beyond these forms. Crucial evidence for the initial storage phase (as well as the productivity of the rule) comes from the observation that children exhibit a so-called U-shaped or ‘change for the worse’ pattern in irregular forms; children start out producing *went, *ate and *felt correctly (as a result of lexical learning), but then go through a stage where they (also) produce *goed, *eated, *feeled (as products of the rule, in competition with the stored form). Precisely how they discover and organize the word pairs in the input and come to recognize the patterns that lead to the postulation of a rule is not clear, but the current consensus is that they do so on the basis of individual, lexicalized forms they can comprehend and produce — and though this example pertains to inflection, it holds for derivation as well (e.g., Clark 2014, Yang 2016).

I argue that this cannot be the case for ordinals, as there does not appear to be comprehension of individual regular ordinals on their own. More importantly, irregular ordinals show no evidence of an initial lexical acquisition stage: children who say *driede ‘threeth’ for the third in line fail to comprehend derde ‘third’. If there were a lexical stage before such overgeneralizations, we would have to say that children temporarily ‘forget’ the meaning of derde when they acquire the rule. I am not aware of any studies that explicitly test children’s understanding of *went in the *goed stage, but I find it hard to believe a child would fail to comprehend a form he previously used flawlessly. As a result, the ordinal rule cannot be acquired from listing lexicalized forms that the child can use (appropriately). However, he does need some prior evidence for a rule to reach the necessary generalization, so he must be keeping track of ordinal numerals in his mental lexicon somehow, and (eventually) pairing them with their corresponding cardinals, even if he has no immediate way of comprehending or using those stored ordinals. Assuming that not all storage is equal is the only way we can account for overgeneralizations as well as the sudden leap in ordinal acquisition: the evidence is being collected and stored (as not yet properly identified forms) until the child is able to use it. I think this “J-pattern” arises when the typical storage phase is too difficult: the cognitive complexity of numerals and the scarce amount of ordinal input makes lexical learning of ordinals a slow and tedious process. The child overcomes these issues by using morphosyntactic knowledge (agreement, nominal modification) and lexical knowledge of cardinals: rules and transparency.
Put differently, acquiring numerical meaning is hard, but the structure helps. This is reminiscent of the early stages of cardinal acquisition, where pre-knowers basically only have a salient structure in which to store them (the count list), and a vague idea of what the group of words refers to (cardinalities), but no understanding of the exact forms. For ordinals, the structure is the morphosyntactic context. The form is recognizable enough to know how to group them (thanks to the cardinal stem), the syntactic context tells them ordinals modify singular nouns, but their knowledge is not complete enough to know how to use them exactly, until all the separate pieces fall into place.

Thus, though the notions of rules and transparency can be used interchangeably in some other parts of the book, I think they both play their own role. Transparency helps children identify the morphological complexity, and perhaps helps them store these forms such that they can be retrieved in the first place, so they can be used as input for the rule. The rule is what helps them grasp the (compositional) meaning of the ordinal as a whole. Such a learning strategy would explain why token frequency in itself does not matter for regular ordinals and why analytic ordinals (e.g., *car three*) are no particular challenge, either: children can simply use the syntactic cues they already had in place, provided their understanding of the cardinal root is sufficiently solid. This is also why – *ste* poses no problems in comprehension on *achtste* ‘eighth’: the suffix may differ from other ordinals the child encounters (note I did not say *knows*) but the structural cues for *achtste* differ in no other way from *negende* ‘ninth’ or *zesde* ‘sixth’, for example.

Again, that solid numerical knowledge is hard to come by. Though cardinal numerals are much more frequent than ordinal numerals and much more likely to be routinely practiced than ordinals (see also Wiese 2003), children take years to map the initial cardinals to a given numerosity. No wonder, then, that irregular ordinals are so hard. Irregular ordinal acquisition is more like acquiring cardinals, i.e., is lexical in nature, but is much more challenging given that there is far less evidence to go by. Irregular ordinals thus illustrate that even for CP-knowers, mapping a form to an exact numerical meaning is cumbersome. This explains why English learners make use of a rule: it is months more efficient than lexical number-word learning. *Second* and *third* might be relatively frequent for ordinals but low-frequent in any real sense. Input for regular ordinals, on the other hand, is supported by syntax. That syntactic support is a useful tool is evident from the observation that
children can readily interpret ordinals before they can produce them (see Chapter III).

In summary, what I hope to have shown here is that nothing in the ordinal acquisition pattern should be taken for granted. At the very beginning of this book, I stated that instead of concluding but of course, perhaps we should be asking but why. There, I was referring mostly to the fact that irregular ordinals are more difficult than regular ones, and throughout this work I have argued that rule-based acquisition was not necessarily the only learning strategy we could have posited, regardless of what our initial intuition was. By now, it should be clear that while the rule-based pattern nonetheless seems to be the most plausible analysis, the acquisition path children follow in the process is also atypical. Although we may be inclined to focus on the economy involved in linguistic productivity, the difference between a ‘U-shape’ (past tense) and a ‘J-shape’ (ordinals) is not really about the rule itself, but about the (in)convenience of lexical learning, and shows we should not take the lexical foundation of productivity for granted. Not all rule-learning is equal, in part because not all storage is equal.

Basically, my account of this data calls upon the reader’s willingness to be surprised and to view the acquisition process from different angles. The metaphor I have come to use to illustrate this came to me while waiting at a bus stop in Takoma Park, where I saw a little heart in the grass by the sidewalk. It turned out to be half a walnut in its shell — not the usual way city dwellers see walnuts. Most store-bought walnuts might sooner resemble a brain (the shell) or a pair of lungs (half, out of its shell). The moral of the story is that what you see in a walnut, and recognizing how the parts fit into the whole, depends largely on how you approach it. The same holds for the findings discussed here: more than what you get at first sight, and not necessarily what you would normally expect to see.
References


Huang, Yi Ting, Elizabeth S. Spelke, & Jesse Snedeker. 2010. When is four far more than three? Children’s generalization of newly acquired number words. *Psychological Science* 21, 600–606.


Izard, Véronique, Pierre Pica, Elizabeth S. Spelke & Stanislas Dehaene. 2008. Exact equality and successor function: Two key concepts on the
path towards understanding exact numbers. Philosophical Psychology 21(4), 491-505.


Appendix

This appendix contains the lists of stimuli used for each of the four studies presented in this dissertation, plus a description of the order in which the stimuli were administered.

Study 1: Chapter II, Dutch comprehension
All children completed a full set of stimuli (see Table 2) in a total of two sessions, but not all in the same order.¹ Children were presented the stimuli in one of the following six logically possible orders in the first session. The order was assigned pseudo-randomly, so that roughly half of the tested participants started with Session A and the other half with Session B. Children completed the remaining stimuli in the second session, where they were assigned one of eight orders for that set (i.e., one of the B orders if they did an A-set in the first session, A if they started with the B-set in the first session). Each session always started with the practice trials (labelled in the tables as T1 and T2). All stimuli made use of nouns that were clearly count nouns in the target language.

Table 1: Possible orders for administering the test sets

<table>
<thead>
<tr>
<th>Session Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(^{st}) half</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>1 A1 forward</td>
</tr>
<tr>
<td>2 A2 forward</td>
</tr>
<tr>
<td>3 A1 backward</td>
</tr>
<tr>
<td>4 A2 backward</td>
</tr>
<tr>
<td>5 A1 forward</td>
</tr>
<tr>
<td>6 A2 forward</td>
</tr>
<tr>
<td>7 A1 backward</td>
</tr>
<tr>
<td>8 A2 backward</td>
</tr>
</tbody>
</table>

¹ Note that a full set did not include the conditions negeren ‘nine’ or negende ‘ninth’ for the first group of children who participated. These trials received a test number with a ‘b’ to indicate they were added later, without affecting the original numbering otherwise. Children who participated later completed 77 trials (the original 71 plus 3 trials each for the added conditions).
Table 2: Stimuli used in Study 1 (Chapter II, Dutch comprehension)

<table>
<thead>
<tr>
<th></th>
<th>Session A1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Trial</strong></td>
</tr>
<tr>
<td>1</td>
<td>T1</td>
</tr>
<tr>
<td>2</td>
<td>T2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
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<tr>
<td>6</td>
<td>4</td>
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<tr>
<td>7</td>
<td>5</td>
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<tr>
<td>8</td>
<td>6</td>
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<tr>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>8b</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>11</td>
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<tr>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>16</td>
<td>13</td>
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<td>17</td>
<td>14</td>
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<tr>
<td>18</td>
<td>15</td>
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<tr>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td><strong>Session A2</strong></td>
</tr>
<tr>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>25</td>
<td>22</td>
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<tr>
<td>26</td>
<td>23</td>
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<td>27</td>
<td>24</td>
</tr>
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<td>28</td>
<td>25</td>
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<td>29</td>
<td>26</td>
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<td>30</td>
<td>27</td>
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<tr>
<td>31</td>
<td>28</td>
</tr>
<tr>
<td>32</td>
<td>29</td>
</tr>
<tr>
<td>33</td>
<td>30</td>
</tr>
<tr>
<td>34</td>
<td>30b</td>
</tr>
<tr>
<td>35</td>
<td>31</td>
</tr>
<tr>
<td>36</td>
<td>32</td>
</tr>
<tr>
<td>37</td>
<td>33</td>
</tr>
<tr>
<td>38</td>
<td>34</td>
</tr>
<tr>
<td>39</td>
<td>34b</td>
</tr>
<tr>
<td>40</td>
<td>35</td>
</tr>
</tbody>
</table>
### Session B1

<table>
<thead>
<tr>
<th>#</th>
<th>Trial</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>toeter die vooraan staat</td>
<td>party horn that’s at the front</td>
</tr>
<tr>
<td>T2</td>
<td>kar die achteraan staat</td>
<td>wagon that’s at the back</td>
</tr>
<tr>
<td>36</td>
<td>een trommel die kleiner is</td>
<td>a drum that’s smaller</td>
</tr>
<tr>
<td>37</td>
<td>de eerste vlieger</td>
<td>the first kite</td>
</tr>
<tr>
<td>38</td>
<td>de laatste hond</td>
<td>the last dog</td>
</tr>
<tr>
<td>39</td>
<td>de eerste boot</td>
<td>the first boat</td>
</tr>
<tr>
<td>39b</td>
<td>de negende robot</td>
<td>the ninth robot</td>
</tr>
<tr>
<td>40</td>
<td>het dikste boek</td>
<td>the fattest book</td>
</tr>
<tr>
<td>41</td>
<td>de derde spaarpot</td>
<td>the third piggybank</td>
</tr>
<tr>
<td>42</td>
<td>de vierde beer</td>
<td>the fourth bear</td>
</tr>
<tr>
<td>43</td>
<td>het grootste kussen</td>
<td>the biggest pillow</td>
</tr>
<tr>
<td>44</td>
<td>het laatste waterpistool</td>
<td>the last water gun</td>
</tr>
<tr>
<td>45</td>
<td>het achtste vliegtuig</td>
<td>the eighth airplane</td>
</tr>
<tr>
<td>46</td>
<td>springtouw dat langer is</td>
<td>jump rope that’s longer</td>
</tr>
<tr>
<td>47</td>
<td>de derde auto</td>
<td>the third car</td>
</tr>
<tr>
<td>48</td>
<td>de middelste trui</td>
<td>the middle–st sweater</td>
</tr>
<tr>
<td>49</td>
<td>de tweede (bad)eend</td>
<td>the second (rubber) duck (lit: ‘bath duck’)</td>
</tr>
<tr>
<td>50</td>
<td>de grootste radio</td>
<td>the biggest radio</td>
</tr>
<tr>
<td>51</td>
<td>de meeste knikkers</td>
<td>the most marbles</td>
</tr>
<tr>
<td>52</td>
<td>de achtste olifant</td>
<td>the eighth elephant</td>
</tr>
<tr>
<td>53</td>
<td>een broek die langer is</td>
<td>a pair of pants that’s longer</td>
</tr>
<tr>
<td>54</td>
<td>de middelste muis</td>
<td>the middle–st mouse</td>
</tr>
<tr>
<td>55</td>
<td>een poes die dikker is</td>
<td>a cat that’s fatter</td>
</tr>
<tr>
<td>56</td>
<td>de tweede slee</td>
<td>the second sled</td>
</tr>
<tr>
<td>57</td>
<td>de eerste fiets</td>
<td>the first bike</td>
</tr>
<tr>
<td>58</td>
<td>de derde zwemband</td>
<td>the third pool float (shaped like a giraffe)</td>
</tr>
<tr>
<td>59</td>
<td>de meeste blokken</td>
<td>the most blocks</td>
</tr>
<tr>
<td>59b</td>
<td>de negende gieter</td>
<td>the ninth watering can</td>
</tr>
<tr>
<td>60</td>
<td>een jas die langer is</td>
<td>a coat that’s longer</td>
</tr>
<tr>
<td>61</td>
<td>de tweede trein</td>
<td>the second train</td>
</tr>
<tr>
<td>62</td>
<td>de vierde bus</td>
<td>the fourth bus</td>
</tr>
<tr>
<td>63</td>
<td>een beker die kleiner is</td>
<td>a cup that’s smaller</td>
</tr>
<tr>
<td>64</td>
<td>de meeste pleisters</td>
<td>the most band aids</td>
</tr>
<tr>
<td>64b</td>
<td>de negende dino</td>
<td>the ninth dinosaur</td>
</tr>
<tr>
<td>65</td>
<td>de middelste muts</td>
<td>the middle–st hat</td>
</tr>
<tr>
<td>66</td>
<td>de dikste frieten</td>
<td>the fattest fries (thick slices)</td>
</tr>
<tr>
<td>67</td>
<td>het achtste hobelpaard</td>
<td>the eighth rocking horse</td>
</tr>
<tr>
<td>68</td>
<td>een kam die kleiner is</td>
<td>a comb that’s smaller</td>
</tr>
<tr>
<td>69</td>
<td>de vierde step</td>
<td>the fourth scooter</td>
</tr>
<tr>
<td>70</td>
<td>de grootste zonnebril</td>
<td>the biggest (pair of) sunglasses</td>
</tr>
<tr>
<td>71</td>
<td>de laatste vrachtauto</td>
<td>the last truck</td>
</tr>
</tbody>
</table>
Study 2: Chapter III, Dutch production and comprehension
All children completed the production session before the comprehension session. The stimuli in the production session were presented in one of two orders, namely either in the order presented in the table below or in the opposite order. Each child started with the practice trials first.

Table 3: Production stimuli used in Study 2, Session 1 (Chapter III)

<table>
<thead>
<tr>
<th>#</th>
<th>Trial</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>toeter die vooraan staat</td>
<td>party horn that’s at the front</td>
</tr>
<tr>
<td>T2</td>
<td>kar die achteraan staat</td>
<td>wagon that’s at the back</td>
</tr>
<tr>
<td>T3</td>
<td>helikopter (in het midden)</td>
<td>helicopter (in the middle)</td>
</tr>
<tr>
<td>1</td>
<td>de vierde beer</td>
<td>the fourth bear</td>
</tr>
<tr>
<td>2</td>
<td>de tweede (bad)eend</td>
<td>the second (rubber) duck (lit: ‘bath duck’)</td>
</tr>
<tr>
<td>3</td>
<td>het achtste hobelpaard</td>
<td>the eighth rocking horse</td>
</tr>
<tr>
<td>4</td>
<td>de eerste boot</td>
<td>the first boat</td>
</tr>
<tr>
<td>5</td>
<td>de zesde vork</td>
<td>the sixth fork</td>
</tr>
<tr>
<td>6</td>
<td>het laatste waterpistool</td>
<td>the last water gun</td>
</tr>
<tr>
<td>7</td>
<td>de derde auto</td>
<td>the third car</td>
</tr>
<tr>
<td>8</td>
<td>de negende gieter</td>
<td>the ninth watering can</td>
</tr>
<tr>
<td>9</td>
<td>de tweede slee</td>
<td>the second sled</td>
</tr>
<tr>
<td>10</td>
<td>de zesde sneeuwpop</td>
<td>the sixth snowman</td>
</tr>
<tr>
<td>11</td>
<td>de vierde bus</td>
<td>the fourth bus</td>
</tr>
<tr>
<td>12</td>
<td>de eerste fiets</td>
<td>the first bike</td>
</tr>
<tr>
<td>13</td>
<td>de laatste hond</td>
<td>the last dog</td>
</tr>
<tr>
<td>14</td>
<td>het achtste vliegtuig</td>
<td>the eighth airplane</td>
</tr>
<tr>
<td>15</td>
<td>de eerste vlieger</td>
<td>the first kite</td>
</tr>
<tr>
<td>16</td>
<td>de derde spaarpot</td>
<td>the third piggy bank</td>
</tr>
<tr>
<td>17</td>
<td>de tweede trein</td>
<td>the second train</td>
</tr>
<tr>
<td>18</td>
<td>de negende robot</td>
<td>the ninth robot</td>
</tr>
<tr>
<td>19</td>
<td>de derde zwemband</td>
<td>the third pool float (giraffe-shaped)</td>
</tr>
<tr>
<td>20</td>
<td>de achtste olifant</td>
<td>the eighth elephant</td>
</tr>
<tr>
<td>21</td>
<td>de negende dino</td>
<td>the ninth dinosaur</td>
</tr>
<tr>
<td>22</td>
<td>de laatste vrachtauto</td>
<td>the last truck</td>
</tr>
<tr>
<td>23</td>
<td>de vierde step</td>
<td>the fourth scooter</td>
</tr>
<tr>
<td>24</td>
<td>de zesde broek</td>
<td>the sixth (pair of) pants</td>
</tr>
</tbody>
</table>

The comprehension test also started with practice trials, then proceeded in one of eight logically possible orders. All children completed a full set of stimuli, but not all in the same order. The order was assigned pseudorandomly, so that roughly half of the tested participants started with Session 2A and the other half with Session 2B, along the lines of what is described for the first half of Table 1. All stimuli made use of nouns that were clearly count nouns in the target language.
Table 4: Comprehension stimuli used in Study 2, Session 2 (Chapter III)

<table>
<thead>
<tr>
<th></th>
<th>Trial</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>toeter die vooraan staat</td>
<td>party horn that’s at the front</td>
</tr>
<tr>
<td>T2</td>
<td>kar die achteraan staat</td>
<td>wagon that’s at the back</td>
</tr>
<tr>
<td>1</td>
<td>één tandenborstel</td>
<td>one toothbrush</td>
</tr>
<tr>
<td>2</td>
<td>de vierde zonnebril</td>
<td>the fourth (pair of) sunglasses</td>
</tr>
<tr>
<td>3</td>
<td>acht stiften</td>
<td>eight markers</td>
</tr>
<tr>
<td>4</td>
<td>de *drie–de bril</td>
<td>the *three–th (pair of) glasses</td>
</tr>
<tr>
<td>5</td>
<td>2 puzzels</td>
<td>two puzzles</td>
</tr>
<tr>
<td>6</td>
<td>de negende aap</td>
<td>the ninth monkey</td>
</tr>
<tr>
<td>7</td>
<td>de *drie–de trompet</td>
<td>the three–th trumpet</td>
</tr>
<tr>
<td>8</td>
<td>één telefoon</td>
<td>one telephone</td>
</tr>
<tr>
<td>9</td>
<td>de laatste tent</td>
<td>the last tent</td>
</tr>
<tr>
<td>10</td>
<td>de negende egel</td>
<td>the ninth hedgehog</td>
</tr>
<tr>
<td>11</td>
<td>één camera</td>
<td>one camera</td>
</tr>
<tr>
<td>12</td>
<td>de drie–de motor</td>
<td>the three–th motorcycle</td>
</tr>
<tr>
<td>13</td>
<td>de vierde schaar</td>
<td>the fourth (pair of) scissors</td>
</tr>
<tr>
<td>14</td>
<td>zes ballen</td>
<td>six balls</td>
</tr>
<tr>
<td>15</td>
<td>de *een–ste helm</td>
<td>the one–th</td>
</tr>
<tr>
<td>16</td>
<td>acht bananen</td>
<td>eight bananas</td>
</tr>
<tr>
<td>17</td>
<td>twee stoelen</td>
<td>two chairs</td>
</tr>
<tr>
<td>18</td>
<td>de negende hamer</td>
<td>the ninth hammer</td>
</tr>
<tr>
<td>19</td>
<td>de *een–ste lepel</td>
<td>the one–st spoon</td>
</tr>
<tr>
<td>20</td>
<td>zes kussens</td>
<td>six pillows</td>
</tr>
<tr>
<td>21</td>
<td>de laatste pop</td>
<td>the last doll</td>
</tr>
<tr>
<td>22</td>
<td>twee emmers</td>
<td>two buckets</td>
</tr>
<tr>
<td>23</td>
<td>de *een–ste duikbril</td>
<td>the one–st diving goggles</td>
</tr>
<tr>
<td>24</td>
<td>de vierde kabouter</td>
<td>the fourth gnome</td>
</tr>
<tr>
<td>25</td>
<td>acht sleutels</td>
<td>eight keys</td>
</tr>
<tr>
<td>26</td>
<td>de laatste muis</td>
<td>the last mouse</td>
</tr>
<tr>
<td>27</td>
<td>zes boeken</td>
<td>six books</td>
</tr>
<tr>
<td>28</td>
<td>de zesde raket</td>
<td>the sixth rocket</td>
</tr>
<tr>
<td>29</td>
<td>het derde konijn</td>
<td>the third bunny</td>
</tr>
<tr>
<td>30</td>
<td>4 onderbroeken</td>
<td>four (pairs of) underpants</td>
</tr>
<tr>
<td>31</td>
<td>de tweede wipkip</td>
<td>the second spring rider (shaped like a chick)</td>
</tr>
<tr>
<td>32</td>
<td>de eerste theepot</td>
<td>the first tea pot</td>
</tr>
<tr>
<td>33</td>
<td>negen ballonnen</td>
<td>nine balloons</td>
</tr>
<tr>
<td>34</td>
<td>de eerste glijbaan</td>
<td>the first slide</td>
</tr>
<tr>
<td>35</td>
<td>de achtste koe</td>
<td>the eighth cow</td>
</tr>
<tr>
<td>36</td>
<td>de tweede poppenwagen</td>
<td>the second stroller</td>
</tr>
<tr>
<td>37</td>
<td>drie T-shirts</td>
<td>three t-shirts</td>
</tr>
<tr>
<td>38</td>
<td>vier zwembroeken</td>
<td>four (pairs of) swim trunks</td>
</tr>
<tr>
<td>39</td>
<td>de eerste lamp</td>
<td>the first lamp</td>
</tr>
<tr>
<td>40</td>
<td>drie petten</td>
<td>three caps</td>
</tr>
</tbody>
</table>
Study 3: Chapter IV, Dutch comprehension

All children completed a full set of stimuli in a total of two sessions, but not all in the same order. See Study 1 and Table 1 for the procedural details regarding test order. All stimuli made use of nouns that were clearly count nouns in the target language.

Table 6: Stimuli used in Study 3 (Chapter IV, Dutch Comprehension)

<table>
<thead>
<tr>
<th>#</th>
<th>Trial</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>toeter die vooraan staat</td>
<td>party horn that’s at the front</td>
</tr>
<tr>
<td>T2</td>
<td>kar die achteraan staat</td>
<td>wagon that’s at the back</td>
</tr>
<tr>
<td>1</td>
<td>konijn drie</td>
<td>bunny three</td>
</tr>
<tr>
<td>2</td>
<td>negen snoepjes</td>
<td>nine candies</td>
</tr>
<tr>
<td>3</td>
<td>de zesde vork</td>
<td>the sixth fork</td>
</tr>
<tr>
<td>4</td>
<td>poes acht</td>
<td>cat eight</td>
</tr>
<tr>
<td>5</td>
<td>de tweede slee</td>
<td>the second sled</td>
</tr>
<tr>
<td>6</td>
<td>een tent</td>
<td>a tent</td>
</tr>
<tr>
<td>7</td>
<td>de* een–ste duikbril</td>
<td>the *one–st diving mask</td>
</tr>
<tr>
<td>8</td>
<td>negen ballonnen</td>
<td>nine balloons</td>
</tr>
<tr>
<td>9</td>
<td>krokodil drie</td>
<td>crocodile three</td>
</tr>
<tr>
<td>10</td>
<td>één camera</td>
<td>one camera</td>
</tr>
<tr>
<td>11</td>
<td>de kam die in het midden is</td>
<td>the comb that’s in the middle</td>
</tr>
<tr>
<td>12</td>
<td>de tweede trein</td>
<td>the second train</td>
</tr>
<tr>
<td>13</td>
<td>de *een–ste helm</td>
<td>the *one–st helmet</td>
</tr>
<tr>
<td>14</td>
<td>koe acht</td>
<td>cow eighth</td>
</tr>
<tr>
<td>15</td>
<td>één tandenborstel</td>
<td>one toothbrush</td>
</tr>
<tr>
<td>16</td>
<td>tractor acht</td>
<td>tractor eight</td>
</tr>
<tr>
<td>17</td>
<td>de zesde broek</td>
<td>the seventh (pair of) pants</td>
</tr>
<tr>
<td>18</td>
<td>negen feesthoedjes</td>
<td>nine party hats</td>
</tr>
</tbody>
</table>
### APPENDIX

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>de *een–ste lepel</td>
<td>the *one–st spoon</td>
</tr>
<tr>
<td>20</td>
<td>de zesde sneeuwpop</td>
<td>the sixth snowman</td>
</tr>
<tr>
<td>21</td>
<td>een pop</td>
<td>a doll</td>
</tr>
<tr>
<td>22</td>
<td>de tweede (bad)eend</td>
<td>the second (rubber) duck (lit: 'bath duck')</td>
</tr>
<tr>
<td>23</td>
<td>slang drie</td>
<td>snake three</td>
</tr>
<tr>
<td>24</td>
<td>één telefoon</td>
<td>one phone</td>
</tr>
</tbody>
</table>

**Session A2**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>theepot één</td>
<td>teapot one</td>
</tr>
<tr>
<td>26</td>
<td>acht bananen</td>
<td>eight bananas</td>
</tr>
<tr>
<td>27</td>
<td>de negende gieter</td>
<td>the ninth watering can</td>
</tr>
<tr>
<td>28</td>
<td>twee stoelen</td>
<td>two chairs</td>
</tr>
<tr>
<td>29</td>
<td>de paraplu die in het midden is</td>
<td>the umbrella that's in the middle</td>
</tr>
<tr>
<td>30</td>
<td>acht sleutels</td>
<td>eight keys</td>
</tr>
<tr>
<td>31</td>
<td>schaar vier</td>
<td>(pair of) scissors four</td>
</tr>
<tr>
<td>32</td>
<td>de *drie–de bril</td>
<td>the *three–th (pair of) glasses</td>
</tr>
<tr>
<td>33</td>
<td>twee puzzels</td>
<td>two puzzles</td>
</tr>
<tr>
<td>34</td>
<td>de negende dino</td>
<td>the ninth dinosaur</td>
</tr>
<tr>
<td>35</td>
<td>lamp één</td>
<td>lamp one</td>
</tr>
<tr>
<td>36</td>
<td>kabouter vier</td>
<td>gnome four</td>
</tr>
<tr>
<td>37</td>
<td>acht stiften</td>
<td>eight markers</td>
</tr>
<tr>
<td>38</td>
<td>een dolfin</td>
<td>a dolphin</td>
</tr>
<tr>
<td>39</td>
<td>de drie–de trompet</td>
<td>the *three–th trumpet</td>
</tr>
<tr>
<td>40</td>
<td>zonnebril vier</td>
<td>(pair of) sunglasses four</td>
</tr>
<tr>
<td>41</td>
<td>twee emmers</td>
<td>two buckets</td>
</tr>
<tr>
<td>42</td>
<td>de negende robot</td>
<td>the ninth robot</td>
</tr>
<tr>
<td>43</td>
<td>glijbaan één</td>
<td>slide one</td>
</tr>
<tr>
<td>44</td>
<td>de *drie–de motor</td>
<td>the *three–th motorcycle</td>
</tr>
<tr>
<td>45</td>
<td>de rugzak die in het midden is</td>
<td>the backpack that's in the middle</td>
</tr>
</tbody>
</table>

**Session B1**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial</td>
<td>Translation</td>
</tr>
<tr>
<td>T1</td>
<td>toeter die vooraan staat</td>
<td>party horn that's at the front</td>
</tr>
<tr>
<td>T2</td>
<td>kar die achteraan staat</td>
<td>wagon that's at the back</td>
</tr>
<tr>
<td>46</td>
<td>de laatste hond</td>
<td>the last dog</td>
</tr>
<tr>
<td>47</td>
<td>poppenwagen twee</td>
<td>stroller two</td>
</tr>
<tr>
<td>48</td>
<td>drie T-shirts</td>
<td>three t-shirts</td>
</tr>
<tr>
<td>49</td>
<td>de *een–de wasknijper</td>
<td>the *one–th clothespin</td>
</tr>
<tr>
<td>50</td>
<td>hamer negen</td>
<td>hammer nine</td>
</tr>
<tr>
<td>51</td>
<td>de vierde bus</td>
<td>the fourth bus</td>
</tr>
<tr>
<td>52</td>
<td>zes ballen</td>
<td>six balls</td>
</tr>
<tr>
<td>53</td>
<td>kruiwagen twee</td>
<td>wheelbarrow two</td>
</tr>
<tr>
<td>54</td>
<td>een bank</td>
<td>a couch</td>
</tr>
<tr>
<td>55</td>
<td>de laatste vrachtauto</td>
<td>the last truck</td>
</tr>
<tr>
<td>56</td>
<td>zes boeken</td>
<td>six books</td>
</tr>
<tr>
<td>57</td>
<td>de *een–de wekker</td>
<td>the *one–th alarm clock</td>
</tr>
</tbody>
</table>
### Study 4: Chapter IV, US English comprehension

All children completed a full set of stimuli in a total of two sessions, but not all in the same order. See Study I and Table 1 for the procedural details regarding test orders. All stimuli made use of nouns that were clearly count nouns in the target language.

<table>
<thead>
<tr>
<th>#</th>
<th>Trial</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>aap negen</td>
<td>monkey nine</td>
</tr>
<tr>
<td>59</td>
<td>de vierde step</td>
<td>the fourth scooter</td>
</tr>
<tr>
<td>60</td>
<td>drie pyjama’s</td>
<td>three (pairs of) pajamas</td>
</tr>
<tr>
<td>61</td>
<td>zes kussens</td>
<td>six pillows</td>
</tr>
<tr>
<td>62</td>
<td>egel negen</td>
<td>hedgehog nine</td>
</tr>
<tr>
<td>63</td>
<td>de *een–de brandweerwagen</td>
<td>the *one–th fire truck</td>
</tr>
<tr>
<td>64</td>
<td>wip kip twee</td>
<td>spring rider two (shaped like a chick)</td>
</tr>
<tr>
<td>65</td>
<td>de vierde beer</td>
<td>the fourth bear</td>
</tr>
<tr>
<td>66</td>
<td>het laatste waterpistool</td>
<td>the last water gun</td>
</tr>
<tr>
<td>67</td>
<td>drie petten</td>
<td>three caps</td>
</tr>
<tr>
<td>68</td>
<td>vier onderbroeken</td>
<td>four (pairs of) underpants</td>
</tr>
<tr>
<td>69</td>
<td>de derde zwemband</td>
<td>the third pool float (giraffe-shaped)</td>
</tr>
<tr>
<td>70</td>
<td>het achtste vliegtuig</td>
<td>the eighth airplane</td>
</tr>
<tr>
<td>71</td>
<td>roeiboot zes</td>
<td>row boat six</td>
</tr>
<tr>
<td>72</td>
<td>de middelste muis</td>
<td>the middle–st mouse</td>
</tr>
<tr>
<td>73</td>
<td>de achtste olifant</td>
<td>the eighth elephant</td>
</tr>
<tr>
<td>74</td>
<td>de eerste fiets</td>
<td>the first bike</td>
</tr>
<tr>
<td>75</td>
<td>vier schepjes</td>
<td>four shovels</td>
</tr>
<tr>
<td>76</td>
<td>de derde auto</td>
<td>the third car</td>
</tr>
<tr>
<td>77</td>
<td>een eekhoorn</td>
<td>a squirrel</td>
</tr>
<tr>
<td>78</td>
<td>de middelste trui</td>
<td>the middle–st sweater</td>
</tr>
<tr>
<td>79</td>
<td>raket zes</td>
<td>rocket six</td>
</tr>
<tr>
<td>80</td>
<td>de eerste boot</td>
<td>the first boat</td>
</tr>
<tr>
<td>81</td>
<td>een helikopter</td>
<td>a helicopter</td>
</tr>
<tr>
<td>82</td>
<td>het achtste hobbelpaard</td>
<td>the eighth rocking horse</td>
</tr>
<tr>
<td>83</td>
<td>vier zwembroeken</td>
<td>four (pairs of) swim trunks</td>
</tr>
<tr>
<td>84</td>
<td>jas zes</td>
<td>coat six</td>
</tr>
<tr>
<td>85</td>
<td>de derde spaarpot</td>
<td>the third piggy bank</td>
</tr>
<tr>
<td>86</td>
<td>de middelste muts</td>
<td>the middle–st mouse</td>
</tr>
<tr>
<td>87</td>
<td>de eerste vlieger</td>
<td>the first kite</td>
</tr>
</tbody>
</table>
Table 6: Stimuli used in Study 4 (Chapter IV, US English Comprehension)

<table>
<thead>
<tr>
<th>Session A1</th>
<th>Session A2</th>
</tr>
</thead>
<tbody>
<tr>
<td># Trial</td>
<td># Trial</td>
</tr>
<tr>
<td>T1</td>
<td>party horn that’s at the front</td>
</tr>
<tr>
<td>T2</td>
<td>wagon that’s at the back</td>
</tr>
<tr>
<td>1</td>
<td>two buckets</td>
</tr>
<tr>
<td>2</td>
<td>snake three</td>
</tr>
<tr>
<td>3</td>
<td>five markers</td>
</tr>
<tr>
<td>4</td>
<td>helicopter four</td>
</tr>
<tr>
<td>5</td>
<td>six books</td>
</tr>
<tr>
<td>6</td>
<td>second duck</td>
</tr>
<tr>
<td>7</td>
<td>two puzzles</td>
</tr>
<tr>
<td>8</td>
<td>monkey seven</td>
</tr>
<tr>
<td>9</td>
<td>one camera</td>
</tr>
<tr>
<td>10</td>
<td>the fifth elephant</td>
</tr>
<tr>
<td>11</td>
<td>slide one</td>
</tr>
<tr>
<td>12</td>
<td>the second train</td>
</tr>
<tr>
<td>13</td>
<td>hedgehog seven</td>
</tr>
<tr>
<td>14</td>
<td>six balls</td>
</tr>
<tr>
<td>15</td>
<td>the sixth fork</td>
</tr>
<tr>
<td>16</td>
<td>the fifth plane</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session B1</th>
<th>Session B2</th>
</tr>
</thead>
<tbody>
<tr>
<td># Trial</td>
<td># Trial</td>
</tr>
<tr>
<td>T1</td>
<td>party horn that’s at the front</td>
</tr>
<tr>
<td>T2</td>
<td>wagon that’s at the back</td>
</tr>
<tr>
<td>34</td>
<td>the third clock</td>
</tr>
<tr>
<td>35</td>
<td>seven sweaters</td>
</tr>
<tr>
<td>36</td>
<td>four umbrellas</td>
</tr>
<tr>
<td>37</td>
<td>cow five</td>
</tr>
<tr>
<td>38</td>
<td>four shovels</td>
</tr>
<tr>
<td>39</td>
<td>the seventh robot</td>
</tr>
<tr>
<td>40</td>
<td>mouse two</td>
</tr>
<tr>
<td>41</td>
<td>three hats</td>
</tr>
<tr>
<td>42</td>
<td>seven balloons</td>
</tr>
<tr>
<td>43</td>
<td>three t-shirts</td>
</tr>
<tr>
<td>44</td>
<td>wheelbarrow two</td>
</tr>
<tr>
<td>45</td>
<td>the last truck</td>
</tr>
<tr>
<td>46</td>
<td>the third piggy (bank)</td>
</tr>
<tr>
<td>47</td>
<td>the first bike</td>
</tr>
<tr>
<td>48</td>
<td>rowboat six</td>
</tr>
<tr>
<td>49</td>
<td>the seventh watering can</td>
</tr>
<tr>
<td>50</td>
<td>rocket three</td>
</tr>
</tbody>
</table>
Summary

Rule and order

Acquiring ordinals in Dutch and English

This dissertation investigates how and when ordinals are acquired in both Dutch and English. The main finding is that children acquire irregular ordinals (e.g., Dutch derde ‘third’) after regular ones (e.g., vierde ‘fourth’), and after analytic ordinals such as auto drie ‘car three’. This holds for comprehension and production and for Dutch as well as English. Put differently, ordinal numerals that can be formed by a rule are more readily understood and produced than ones that cannot. Children also overgeneralize their rule, producing *twoth or *drieth ‘threeth’, for example. Clearly, children cannot simply copy such forms from the language they hear around them; they create these forms themselves after learning that ordinals are made by adding a suffix (–de and –th in these examples) to a cardinal numeral, like two or drie ‘three’.

This may seem obvious or trivial at first sight. For one, a topic as basic as number words must have received ample attention in the literature. For another, many studies have shown that children prefer regular forms over irregular ones and that children are known to make overgeneralization errors (e.g., Pinker 1999). Could ordinal numeral acquisition contribute to any scientific discussion? The answer, I argue, is yes. Not only is the data collected here the first to provide a systematic overview of ordinal acquisition, the account for this data is neither the only nor the most straightforward hypothesis. The short version of this account is that children use morphosyntactic structure to acquire the meaning of ordinal numerals. What makes this interesting, however, is that they do not seem to go through a stage of lexical learning before acquiring that rule. This makes the ordinal acquisition pattern unlike the cardinal pattern (where lexical learning plays a key role, especially at first), and unlike patterns in inflectional or derivational morphology (where children initially store morphologically complex forms, before learning that worked, for example, consists of the stem work and a past tense suffix –ed, and worker of the same stem and the agentive suffix –er). Ordinary as it may seem, ordinal acquisition proves to be a curious case study that can only
be understood when insights from language acquisition, developmental psychology and numerical cognition are combined.

The introduction of this dissertation briefly touches on each of those perspectives and highlights a uniquely human property of our cognition: the ability to conceive of large, exact numbers such as 4733 (Carey 2009, Dehaene 1997, Dehaene 2009, Spelke & Kinzler 2007). We share, however, the foundations of number, as both animals and humans have been argued to have access to two core knowledge systems of number. The first, the Object Tracking System or OTS, is not strictly numerical but can be used for keeping track of individual objects up to a limit of three or four — not even close to 4733. The second, the Approximate Number System or ANS, is sensitive to ratios rather than individuals, and works best with larger quantities. The ANS would be able to tell that it is more than 3123 or less than 7171, but not that it differs from 4732 or 4734 by exactly one. Obviously, however, human adults have no difficulty discerning these numbers, and various scholars have argued that we can combine these two systems and overcome their boundaries thanks to language (most notably Carey 2009; Hurford 1987; Spelke 2011, 2017).

I use that claim as a springboard to discuss patterns in the development of cardinal numerals (one, two, three) before shifting the focus to ordinal numerals (fourth, fifth, sixth). Cardi nals have been in the spotlight of numerical development for decades (starting with Wynn 1990), but ordinals have received strikingly little attention in the literature, despite them having the same conceptual foundation as cardinals. Not only are the same core knowledge systems presumed to be involved, the counting principles necessary to use ordinals productively are almost identical. This is therefore the starting point in Chapter II, where I ask whether the pattern and timing of ordinal acquisition differ from that of cardinals, and if so, whether these differences can be related to linguistic factors, since they are typically derived from cardinals. As a result, answering that question requires understanding cardinal acquisition first.

Cardinal acquisition entails learning that cardinals refer to exact, discrete quantities, and learning how to determine which cardinal to use. Children slowly acquire the meanings of the numerals one through four in a slow and stepwise fashion. As pre-knowers, children know numerals refer to quantities, though they do not know which ones exactly, and they might not be able to recite the count list in the correct order. As one-knowers, they know that one cookie refers to exactly one cookie, and that any other number must be more than that. Knowledge of two, three and
four, is subsequently accrued in that order, before a conceptual leap happens. They progress from being 'subset-knowers' (children who only comprehend a subset of the numbers in their count list) to CP-knowers, i.e., children who know the necessary counting principles (hence CP) and are able to distill the meanings of other numerals. These principles are the one-to-one correspondence principle (each numeral refers to a single item), the stable order principle (numerals have to be recited in a particular order) and the cardinal principle (the numeral assigned to the last item counted reveals the cardinality of the set). Ordinals require the first two of these principles, but the cardinality principle is replaced by the ordinality principle: the last numeral counted now refers to the position or rank of an individual item.

To compare ordinals to cardinals, I adapted a classic cardinal comprehension task known as a ‘Give Me’ task (Wynn 1992, Le Corre & Carey 2007). In this version, children had to help a monkey pack his suitcase by correctly identifying the right (number of) objects from a line. I tested 77 children acquiring Dutch as their first language on the cardinals and ordinals for one, two, three, and four (to see if there was evidence for a tiered pattern in ordinals), as well as eight and nine (to see what happens with higher numerals and to categorize CP-knowers). I also tested their knowledge of the degrees of comparison for veel ‘many’, weinig ‘few’, groot ‘big’, klein ‘small’ and lang ‘long’ as a type of control condition.

Though I could have investigated any language, the focus here is on Dutch. Dutch is similar enough to English to predict comparable patterns in cardinals, but has an ordinal list that differs from the few languages that have been studied in the ordinal literature (Fischer & Beckey 1990 and Miller et al. 2000 for English; Miller et al. 2000 for Chinese, Colomé & Noël 2012 for French; Trabandt et al. 2015 for German). Dutch has two ordinal suffixes: –de for most ordinals under twenty, and –ste for most other ordinals that do not end in a cardinal under twenty, and a mostly regular ordinal list. The exceptions are eerste ‘first’ (though actually a superlative, not an ordinal, cf. Barbiers 2007), derde ‘third’ (root allomorphy, but regular suffix) and achtste ‘eighth’, which has an easily identifiable cardinal root but takes the suffix typically used for higher ordinals.

As expected, the data from this first study reveal nothing surprising in the cardinal domain. Dutch children acquire cardinals in the same stepwise fashion children acquiring other languages do, albeit roughly six months slower. Most children acquiring English in the United States
become CP-knowers at about 3:06, while Dutch children reach that point around their fourth birthday.

The pattern and timing for ordinals, however, is considerably different. For one, children start acquiring ordinals much later: only four-knowers and CP-knowers exhibit understanding of any ordinals. Their knowledge of cardinals is more telling than just their age. For another, there is no evidence for a tiered acquisition pattern. Though some children do understand only eerste ‘first’, the ordinals tweede ‘second’ and higher do not follow in order. Instead, there are children who comprehend the regular ordinals tweede ‘second’, lit: twoth’ and vierde ‘fourth’, and sometimes also achtste ‘eight’ and negende ‘ninth’, but not irregular derde ‘third’. Some children did know all the lower ordinals (through vierde ‘fourth’) but not the higher two, which I argue later in the dissertation is reminiscent of the cardinal pattern, where the OTS boundary also marks a drop in performance. I return to this later.

The difficulties with derde ‘third’ and similarities between regular ordinals would be hard to explain from a lexicalist or frequency-based perspective. The outcome of this study instead suggests transparency is important in ordinal acquisition; a stronger hypothesis would be to say that children deduce the meaning of ordinals by means of a rule. This raises three questions that are investigated in Chapters III and IV. The first pertains to production, the second to different kinds of ordinals, and the third to ordinal acquisition in different languages. Chapter III therefore compares comprehension and production, and also includes forms that are regular but ungrammatical in the comprehension test. The questions addressed are how the development of ordinal production compares to the development of ordinal comprehension, and whether children generalize an ordinal formation rule. Chapter IV compares synthetic ordinals (e.g., de tweede slee ‘the second sled’) to analytic ordinals (e.g., jas zes ‘coat six’) in Dutch and English. All experimental setups are similar to the one in Chapter II, modified such that they answer the questions at hand.

Chapter III presents data from 68 Dutch children (mean age: 5:0) that confirm two key results from the previous chapter. First, CP-knowers did better than the four-knowers, meaning cardinal knowledge is important. Second, CP-knowers could comprehend nearly all ordinals, even the overgeneralized forms *eende ‘one–th’, *eenste ‘one–st’, *driede, ‘threeth’. The only notable exception is derde ‘third’, for which the correct response was given 69% of the time. If children fail to understand an
irregular form but can comprehend a regular counterpart that is not in the input, this suggests children are learning by rule, not rote. *Drie \( \text{d} \)'threeth' can be decomposed into an ordinal suffix and a cardinal root. Decomposition of derde 'third', however, leads children to something they know must be a cardinal, but one they do not recognize, as evidenced by responses like *Hoeveel is der?* 'How many is thir?'

Chapter III also shows that (i) ordinal comprehension precedes production, especially when it comes to irregular forms, and (ii) children overgeneralize the rule in their own speech. Not all irregularities are equal, however: though children produce both *drie \( \text{d} \)'threeth', and *achtde rather than achtste 'eighth' (with the other ordinal suffix), achtste is notably harder to get right. I argue that this is because the exact suffix is less crucial for arriving at the correct interpretation, whereas the root is fundamental for comprehension. Ordinals occur in NPs, where they always modify a singular noun. This morphosyntactic context (plus whatever other contextual information in the discourse) could lead you to the appropriate interpretation, as long as you recognize the cardinal root in this complex form, and understand what the cardinal means. In production, however, the rule apparently defaults to –de, and use of –ste has to be acquired separately.

Chapter IV looks at productivity and frequency in the input in two ways: it compares Dutch learners to children acquiring English in the United States, and it compares synthetic ordinals (the fourth chapter) to analytic ones (chapter four). The first comparison tells us something about acquiring less regular ordinal lists, which provide less evidence for the rule. The second allows us to see if it is the synthetic ordinal rule that matters, or whether a syntactic solution will also suffice. These analytic forms are always transparently related to the cardinal, but are admittedly different from synthetic ordinals in when and how they are normally used. Chapter IV goes into all the relevant differences, but they do not really matter: the type of ordinal was not found to play a significant role in ordinal comprehension, as long as we were comparing analytic ordinals to regular synthetic ordinals. Put differently, kabouter vier ‘gnome four’ elicited similar responses to de vierde bus ‘the fourth bus’, but the second sled and the fifth plane elicited fewer correct responses than e.g., mouse two or cat five. Again, the most important factor here is regularity: irregular forms elicited fewer correct responses than regular ones.

These findings not only hold for Dutch learners (2;08–4;11, M = 4;05, N = 70), but also for children acquiring English in the U.S. (3;3–5;3, M =
That is actually quite surprising, because it entails that children acquiring English also use a rule and are not tempted to acquire ordinals lexically, despite the more difficult ordinal count list. Fourth only starts to resemble a rule in the company of sixth and higher ordinals, and irregular ordinals are more frequent than most regular ones. Perhaps this is why Dutch children outperform children acquiring English: Dutch children are late to acquire cardinals, but ordinals are much easier to acquire once the cardinal knowledge is in place.

The evidence children can consider could be linked to a more fundamental difference between both groups of learners. Some Dutch children had difficulty with the higher ordinals in the experiment, i.e., zesde ‘sixth’, achtste ‘eighth’ and negende ‘ninth’, but not with the lower regular ordinals tweede ‘second’ and vierde ‘fourth’. This difference between lower and higher ordinals did not appear in the English-speaking group, but it did arise in the Dutch group discussed in Chapter II. I point out in Chapter IV and V that this difference between low (≤4) and high ordinals is reminiscent of the effect of the OTS boundary reported for cardinal acquisition, where the incremental lexical acquisition of cardinals stops at four and a generalization occurs.

Integrating (co-activating) OTS and ANS is presumably hard, and the ordinal data would suggest overcoming the boundaries of these systems is not something that happens once (as children become CP-knowers), but is something that happens iteratively. If this is true, then this could help us understand the difference between Dutch and English above. The hypothesis is then that Dutch children can make use of evidence for an ordinal rule within the OTS boundary, making it relatively easy for them to acquire lower ordinals: the counting principles, OTS, and the ordinal rule suffice. Higher ordinals, on the other hand, require integrating OTS and ANS as well, and this additional process proves to be too hard for some children. English learners face a different challenge, because sufficient evidence for the rule only appears after the OTS boundary, meaning that they must have overcome the cost of integrating their number systems before they can acquire the rule.

Chapter V concludes this work with a discussion of why children make use of a rule and why the ordinal rule cannot be acquired like other better-studied types of morphology, such as past tense –ed. The why-question is relatively easy to answer: because acquiring ordinals lexically is less economical. We know from the cardinal literature that number word learning is extremely trying, despite the explicit training children receive
and despite the overall prevalence of numbers in the input. Children receive much less (salient) input for ordinals, but ordinals do come with an added benefit, namely a clear morphosyntactic environment. Hence, I propose that children would rather use the lexical (cardinal) knowledge they already have, and combine that with morphosyntactic knowledge (agreement, nominal modification, the ordinal affix), instead of storing individual ordinals one by one. Transparency helps children identify ordinals as complex forms, and perhaps allows them to store these otherwise unanalyzed forms until they can be used as input for the rule. The rule is what helps them grasp the meaning of the ordinal as a whole. The cardinals are acquired via storage, ordinals via computation.

This is incompatible with what is typically described for the development of morphological productivity in children, where it is generally assumed that children store forms such as *washed* before decomposing them into *wash* and *–ed* for the past tense (cf. Pinker 1999, Yang 2016, Lignos & Yang 2016). Irregular forms such as *ate* and *went* are also stored. Discovery of the rule then leads to a so-called U-shape: children temporarily overgeneralize the rule in forms they previously produced correctly: *eated, *goed*, et cetera. If this pattern applied to ordinals, *derde* would be expected to be produced (and thus comprehended) before the *driede* stage, but overgeneralization errors in ordinals (e.g., *driede* ‘threeth’) co-occur in children who do not understand *derde*. It seems unlikely that a child would forget the meaning of a word he previously used correctly. Hence, the ordinal pattern is more of a “J-shape”, where there is no comprehension or production, and thus no storage, before the rule becomes productive. A storage account would also not predict simultaneous acquisition of multiple (regular) forms at once, making an initial storage phase less likely.

As a result, ordinal acquisition may seem intuitive and straightforward at first, but turns out to be more than atypical on second thought. This dissertation thus makes a meaningful contribution in two ways, the most concrete of which is the developmental pathway proposed in (1), copied from Chapter V.

(1) **Stages in ordinal acquisition**

(i) Children use morphosyntactic cues (such as the fact that ordinals combine with singular nouns whereas most cardinals combine with plurals) to discover that ordinals refer to individuals, not sets. They
can give you one item when asked for e.g., *the vierde* ‘the fourth’, but it might be the second or the ninth in line.

(ii) Children, when they are at least four-knowers, acquire *eerste* ‘first’ first. This form is acquired relatively early for three reasons. It does not require true counting competence, it is roughly 50% more frequent than *tweede* ‘second’ through *twintigste* ‘twentieth’ combined, and it has been shown to be a superlative (rather than an ordinal) in Dutch (Barbiers 2007), which are acquired early (cf. Syrett 2016). Something similar holds for English.

(iii) Children subsequently acquire the ordinal formation rule (informally: cardinal + suffix = ordinal). Children in this stage can reliably find at least low, regular ordinals if the lower ordinals provide sufficient evidence for the rule, such as in Dutch *tweede* ‘second, lit: two–th’ and *vierde* ‘fourth’. If higher ordinals are needed for the generalization, CP-knowers should comprehend both lower (≤4) and higher (>5) regular ordinals.

(iv) Performance on higher, regular ordinals is (by definition) limited to CP-knowers only, since children who cannot count beyond *four* cannot be expected to count to higher ordinals either. CP-knowers may have difficulty with higher ordinals due to task demands (the further one has to count and maintain one-to-one correspondence, the more demanding the task becomes) but also due to the extra challenge of combining the two core number systems (OTS and ANS) with the ordinal formation rule. For lower ordinals, the ANS need not be recruited, but for higher ordinals, both systems are necessary.

(v) Performance on irregular forms (such as *derde* ‘third’ in comprehension and production, and *achtste* ‘eighth’ in production) follows at some point after acquisition of the rule. Note that this might be before or after performance on higher ordinals improves.

More generally, these data show us how taking different perspectives is important. For one, the pathway above would be less complete without production data complementing comprehension, without the analytic ordinals in comparison with synthetic ones, or without the cross-linguistic angle. For another, the finding that seemed straightforward and obvious turned out to be quite surprising, showing our intuition can be right for the wrong reasons.
Regel en rangorde
De verwerving van rangtelwoorden in het Nederlands en het Engels


Op het eerste gezicht lijkt dit wellicht een open deur. Telwoorden zijn immers zo basaal dat je zou verwachten dat ze inmiddels wel uitgebreid onderzocht zullen zijn. Bovendien is het ook al wel bekend dat kinderen makkelijk regels leren en die regels ook overgeneraliseren (Pinker 1999). Voorbeelden als *loopte (voor liep) en *veler (voor meer) zijn er genoeg. Toch levert dit onderzoek naar rangtelwoorden weldegelijk een originele bijdrage, en wel op twee manieren. Ten eerste zijn de data nieuw: dit is het enige onderzoek dat een systematisch overzicht biedt van rangtelwoordverwerving, en dat proces ook vergelijkt met dat van hoofdtelwoorden. Ten tweede blijken de patronen die we tegenkomen bij nader inzien toch niet zo eenvoudig te verklaren. Ik betoog hier dat
kinderen gebruikmaken van de structuur van taal om de betekenis van rangtelwoorden te achterhalen, en dat dat proces pas goed te begrijpen is als we inzichten uit verschillende vakgebieden (de ontwikkelingspsychologie, de cognitiewetenschap en natuurlijk de taalwetenschap) combineren. Dat kinderen een regel leren is op zichzelf niet zo bijzonder, wel de manier waarop kinderen aan die regel komen en de manier waarop deze wordt ingezet.

In de meeste gevallen leiden kinderen namelijk een regel af uit een aantal voorbeelden die ze eerst stuk voor stuk hebben opgeslagen (lexicaal hebben geleerd). Zo worden bijvoorbeeld *werkte* en *werker* eerst als hele vormen geleerd, en ontdekken kinderen pas later dat deze vormen uit twee delen bestaan (een stam *werk*, en een achtervoegsel –te of –er), die allebei iets bijdragen aan de betekenis van het geheel. Bij rangtelwoorden lijkt het echter andersom te werken. Dat eerste lexicale stadium, de opslagfase, blijkt namelijk afwezig: we zien bewijs voor een regelfase, waarin ook overgeneralisaties (*driede*) kunnen voorkomen, maar geen bewijs voor het één voor één opslaan van hele vormen. Het lijkt er dus op dat kinderen juist gebruikmaken van de delen om het geheel te leren, en niet andersom. Dat maakt rangtelwoordverwerving anders dan de verwerving van andere productieve morfologie, en ook anders dan hoofdtelwoordverwerving (waarvoor aanvankelijk een puur lexicaal patroon geldt). Dat is op zichzelf al opvallend, maar werpt ook meteen twee andere vragen op: wat maakt rangtelwoorden zo bijzonder, en waar komt die regel dan vandaan? Zo blijken rangtelwoorden dus toch een curieuze case study te zijn.

In de inleiding van het proefschrift plaats ik de verwervingsvraag in kwestie in een breder kader. Daarin stip ik kort de verschillende perspectieven van hierboven aan, en licht ik een unieke eigenschap van de mens uit: ons vermogen om heel precies met grote getallen, zoals 83 of 4733, om te gaan. (Carey 2009, Dehaene 1997, Dehaene 2009, Spelke & Kinzler 2007). De basis van ons getalbegrip is echter niet zo uniek. Met andere diersoorten delen we een tweetal zelfstandige cognitieve systemen, zogenaamde kernkennisystemen, die voor de verwerking van hoeveelheden kunnen worden ingezet. Het eerste systeem, het zogenaamde Object Tracking System (OTS) is niet per se numeriek van aard, maar kan heel algemeen worden ingezet om maximaal drie of vier individuele objecten (geluiden, et cetera) bij te houden. Met een bovengrens van vier komen we dus niet eens in de buurt van 4733. Het andere systeem is juist niet gevoelig voor afzonderlijke objecten en daarmee niet geschikt voor kleine hoeveelheden. Het Approximate
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*Number System (ANS)* is er juist voor schattingen, verhoudingen, en relatief grote aantallen. Als je ANS wordt geconfronteerd met 4733 rijstkorrels, zou het kunnen schatten dat dat meer is dan 3123 of minder dan 7171, maar niet dat het precies 1 korrel verschilt van 4734 of 4732. Geen van beide kernkennisystemen stelt ons dus in staat om goed om te gaan met grotere exacte aantallen, en toch zal geen enkele lezer van deze alinea moeite hebben deze getallen te begrijpen. Kennelijk kunnen we die twee systemen koppelen en hun afzonderlijke beperkingen overstijgen, en volgens verschillende onderzoekers hebben we dat vermogen te danken aan taal (Carey 2009, Hurford 1987, Spelke 2011, 2017).

Hoe die koppeling precies werkt, en wat de rol van taal precies is, zijn eigenlijk vragen die losstaan van de rest van dit proefschrift, maar de interesse in de ontwikkeling van getalbegrip heeft wel geleid tot een lange, uitgebreide reeks aan onderzoeken naar hoe kinderen uit allerlei delen van de wereld hoofdtelwoorden verwerven. Die data zijn wel van belang voor dit proefschrift. Om productief met rangtelwoorden om te gaan, heb je immers dezelfde kernkennisystemen nodig, maar ook goeddeels dezelfde telprincipes. Beide soorten telwoorden delen dezelfde conceptuele basis en zoals we hebben gezien zijn onze rangtelwoorden ook afgeleid van hoofdtelwoorden. Desalniettemin blijkt gericht onderzoek naar rangtelwoordontwikkeling buitengewoon moeilijk te vinden. Hoofdstuk II draait daarom om de vraag in hoeverre de verwerving van rangtelwoorden lijkt op die van hoofdtelwoorden, en of eventuele verschillen dan wellicht verklaard kunnen worden door factoren die aan taal gerelateerd zijn.

Om deze vragen te beantwoorden, moeten we dus eerst een goed beeld hebben van hoe hoofdtelwoordverwerving precies verloopt. Uit Wynn (1992) en de vele studies die daarop volgden, blijkt niet alleen dat ‘leren tellen’ verre van eenvoudig is en veel tijd kost, maar ook dat de fases die kinderen doorlopen over de hele wereld dezelfde zijn. De duur van het verwervingsproces kan behoorlijk verschillen, maar het patroon is universeel. Kinderen doorlopen een vijftal stadia waarin ze langzaam grip krijgen op wat telwoorden betekenen. Als *pre-kenners* kunnen ze een rijtje getallen opzeggen, al dan niet in de juiste volgorde. Ze begrijpen dan ook dat telwoorden naar aantallen verwijzen, alleen hebben ze nog geen precieze aantallen aan die telwoorden gekoppeld. Het eerste telwoord waaraan ze een precieze hoeveelheid toekennen is *één*: een *één-kener* weet dat *één koekje* naar precies *één* koekje verwijst, maar van andere getallen weet hij dan alleen dat ze ‘meer dan *één*’ moeten betekenen. Stapsgewijs komt er op soortgelijke wijze kennis van *twee*, *drie* en *vier* bij,
waarna kinderen een conceptuele sprong maken: ze ontwikkelen zich van *subset-kenners* (kinderen die een deel, subset, begrijpen van de getallen die ze kunnen opzeggen) naar *CP-kenners*. CP-kenners zijn telvaardige kinderen die de relevante telprincipes (Engels: *counting principles*) onder de knie hebben en voor alle getallen in hun telrij de betekenis kunnen achterhalen. Zo weten ze dat alle getallen in een vaste volgorde worden opgenoemd, dat bij elk object precies één telwoord hoort (het één-op-één-principe), en dat het laatst opgenoemde telwoord antwoord geeft op de vraag *hoeveel* (het cardinaliteitsprincipe). Kortom, een kind kan resultatief tellen, is telvaardig, als hij of zij bij het tellen de juiste volgorde van getallen aanhoudt, niets overslaat, niets dubbel telt, en begrijpt dat als je tot bijvoorbeeld *acht* telt, dat *acht* het totale aantal van de groep getelde objecten aangeeft. Voor rangtelwoorden is vergelijkbare kennis nodig, alleen geldt hier het ordinaliteitsprincipe: het laatst genoemde telwoord zegt nu niet meer iets over een groep objecten, maar alleen over het laatst getelde; het geeft de positie of rangorde van een individueel object aan.

Om de ontwikkeling van hoofd- en rangtelwoorden (cardinalen en ordinalen) te vergelijken, heb ik een klassieke begripstaak uit de literatuur aangepast, een zogenaamde ‘Geef Mij’-taak (Wynn 1992, Le Corre & Carey 2007). In deze versie van de taak vroeg ik kinderen of ze een knuffelaap wilden helpen om zijn koffer in te pakken. Daarvoor moesten ze de juiste (aantallen) objecten uit een rij kiezen en die in een speelgoedkoffertje stoppen. In het onderzoek nam ik verschillende telwoorden mee: *één, twee, drie* en *vier* (om de getrapte ontwikkeling die bij lage telwoorden zichtbaar is te onderzoeken), *acht* en *negen* (om te kijken wat er bij hogere telwoorden gebeurt en om kinderen als CP-kener te kunnen classificeren), en de ordinale tegenhangers hiervan: *eerste, tweede, derde, vierde, achtste, negende*. Verder testte ik ook hun kennis van de trappen van vergelijking van *veel, weinig, groot, klein en lang*. Aan deze eerste studie deden 77 peuters en kleuters mee die het Nederlands als moedertaal hadden.

Is er eigenlijk iets bijzonders aan het Nederlandse (rang)telsysteem? In het Nederlands worden rangtelwoorden gevormd door achter een hoofdtelwoord een suffix te plaatsen, namelijk –*de* bij de meeste telwoorden onder de twintig (bijvoorbeeld *vierde*) en –*ste* bij hogere telwoorden (*twintigste, honderdste, duizendste*). Uitzonderingen op die regel zijn *eerste* (hoewel we aannemen dat *eerste* eigenlijk geen rangtelwoord is, maar een overtreffende trap, cf. Barbiers 2007), *derde*
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Uit dit eerste experiment blijkt dat Nederlandstalige kinderen hoofdtelwoorden, zoals verwacht, op dezelfde stapsgewijze manier verwerven als Engelstalige kinderen. Het enige verschil is dat ze er een paar maanden langer over doen: daar waar Engelstalige kinderen in de Verenigde Staten zo rond de drieënhalf zijn als ze CP-kenner worden, gebeurt dat bij Nederlandstalige kinderen rond hun vierde verjaardag. Zo niet voor de rangtelwoorden: die leren kinderen niet alleen later, maar ook op een andere manier. Kinderen beginnen pas echt iets te begrijpen van rangtelwoorden als ze 4-kenner of CP-kenner zijn. Daarnaast verwerven kinderen rangtelwoorden niet één voor één in de volgorde van de telrij. Er zijn weliswaar kinderen die alleen eerste begrijpen, maar daarna volgen de regelmatige rangtelwoorden, dus niet alleen tweede, maar bijvoorbeeld ook vierde. De onregelmatige vorm derde wordt pas later begrepen. Sommige kinderen hebben meer moeite met de hoge rangtelwoorden achtste en negende dan met derde. Ik zal straks betogen dat dit te maken heeft met de bovengrens van het OTS; het effect van de onderliggende kernkennisystemen is dus niet alleen zichtbaar bij hoofd- maar ook bij rangtelwoorden.

Dat kinderen vergelijkbaar scoren op regelmatige rangtelwoorden en tegelijkertijd relatief laag scoren op derde valt niet goed te begrijpen als je uitgaat van opslag of frequentie als bepalende factor in het verwervingsproces. Daarbij zou je namelijk wel een sequentieel patroon verwachten. Het lijkt er eerder op dat vooral de vorm van die woorden belangrijk is, en dat kinderen gebruikmaken van die vorm (de morfologische regel) om de betekenis te achterhalen. De rest van dit proefschrift onderzoekt in hoeverre dat inderdaad zo is. Ik vergelijk comprehensie en productie, verschillende soorten ordinalen, en
rangtelwoordverwerving in het Nederlands en het Engels. Alle data zijn steeds gebaseerd op hetzelfde experiment als in Hoofdstuk II, dat steeds iets is aangepast om de relevante deelvragen te kunnen beantwoorden.

Hoofdstuk III beschrijft data van 68 Nederlandstalige kinderen (gemiddelde leeftijd: 5;0) die twee belangrijke uitkomsten uit het vorige hoofdstuk bevestigen. Ten eerste begrijpen CP-kenners ook hier meer van rangtelwoorden dan 4-kenners. Dat onderstreept het belang van hoofdtelwoordkennis. Daarnaast valt ook hier op dat CP-kenners minder vaak een goed antwoord geven bij derde dan bij regelmatige ordinalen, zelfs als die vormen niet in het taalaanbod zitten, zoals als *eende of *driede. Dit suggereert dat kinderen niet simpelweg aan het ‘stampen’ zijn, maar dat ze gebruikmaken van morfologische kennis. In de vorm *driede kunnen ze een cardinale stam drie en een rangtelwoordsuffix herkennen. De allomorfie in derde herkennen ze minder snel, al passen ze ook hier decompositie toe, zoals blijkt uit reacties als Hoeveel is derde? Dergelijke vragen laten zien dat ze de betekenis van derde proberen te berekenen met behulp van de morfologische structuur.

Hoofdstuk III laat verder zien dat kinderen (i) rangtelwoorden eerder begrijpen dan dat ze zelf produceren, en (ii) in hun eigen spraak de regel toepassen en overgeneraliseren. Zo zeggen ze zowel *driede (in plaats van derde) als *achtde (in plaats van achtste). Hoewel achtste niet tot begripsproblemen leidt, blijkt die in de productie juist moeilijker te zijn dan derde. Ik vermoed dat dat komt omdat bij achtste de transparantie niet in het gedrang raakt: omdat rangtelwoorden in principe alleen nomina in het enkelvoud modificeren, kunnen kinderen (mits ze weten wat acht betekent, en achtste herkennen als morfologisch geleed) met de cardinale stam en de morfosyntactische context al tot de juiste interpretatie komen. Bij productie vallen ze echter terug op –de als default en moet –ste vervolgens expliciet worden geleerd.

De vraag is of kinderen gebruikmaken van een specifieke morfologische regel, of meer in algemene zin gebruikmaken van taalstructuur. In Hoofdstuk IV vergelijk ik daarom synthetische ordinalen (het vierde hoofdstuk) met analytische ordinalen (hoofdstuk vier). Analytische ordinalen komen minder vaak in het taalaanbod voor, maar ze hebben wel een transparante en regelmatige structuur. De precieze overeenkomsten en verschillen bespreek ik in Hoofdstuk IV, maar eigenlijk is het enige wat ertoe doet de transparante vorm: kinderen blijken analytische ordinalen net zo vaak te begrijpen als synthetische ordinalen, mits het om regelmatige synthetische vormen gaat. Is de
synthetische vorm onregelmatig, dan is het percentage correcte antwoorden hoger bij de analytische tegenhanger. Met andere woorden: kinderen kunnen net zo vaak kabouter vier aanwijzen als de vierde bus, maar wijzen slang drie vaker goed aan dan de derde slang.

Dit geldt niet alleen voor kinderen die Nederlands spreken (2;08–4;11, M = 4;05, N = 70), maar ook voor kinderen die in de V.S. opgroeien met het Engels (3;3–5;3, M = 4;03, N = 35). Zij wijzen mouse two ‘muis twee’ en cat five ‘poes vijf’ namelijk vaker goed aan dan the second sled ‘de tweede slee’ en the fifth plane ‘het vijfde vliegtuig’. Ook hier zien we dus dat kinderen meer correcte antwoorden geven als het rangtelwoord regelmatig is. Deze kinderen maken dus ook gebruik van een regel, en dat is om verschillende redenen verrassend te noemen. Niet alleen kent de Engelse rangtelrij veel uitzonderingen (eigenlijk kunnen we pas vanaf sixth ‘zesde’ beginnen te zien dat er überhaupt sprake is van een regel), ook komen die uitzonderingen vaker in het taalaanbod voor dan de regelmatige vormen. De evidentie voor die regel is dus mager in vergelijking met het aanbod dat Nederlandse kinderen krijgen, en daarom doen Engelslalige kinderen er (in verhouding tot het moment waarop kinderen in beide talen gemiddeld genomen CP-kenner worden) langer over om rangtelwoorden te verwerven.

Een tweede opvallend verschil tussen de Engelse en Nederlandse data is dat er voor het Engels geen verschil is tussen de scores op lagere en hogere rangtelwoorden, terwijl sommige Nederlandse kinderen wel meer moeite hebben met zesde, achtste en negende dan met tweede en vierde. Ik betoog dat dit verschil doet denken aan de effecten van de OTS-grens in hoofdtelwoordverwerving en samenhangt met de eerdergenoemde evidentie voor de ordinale regel. We zien bij de hoofdtelwoorden een conceptuele sprong bij vier, omdat daar de bovengrens van het OTS zit: voor hogere cardinalen moeten OTS en ANS geïntegreerd (gecoactiveerd) worden. De vraag is of die koppeling een eenmalige prestatie is, of iets is wat steeds opnieuw tot stand moet komen, een beetje zoals wanneer je de koppeling indrukt tijdens het autorijden. Is het inderdaad een iteratief proces, dan begrijpen we beide verschillen (zowel het tempo als het patroon) tussen rangtelwoordverwerving in het Nederlands en het Engels. Kinderen die Nederlands leren, kunnen binnen de grenzen van het OTS evidentie vinden voor de ordinale regel (bij tweede en bij vierde). Dat maakt het voor hen relatief eenvoudig om deze lage ordinalen te verwerven: met de telprincipes, het OTS en –de zijn ze er al. Voor de hogere ordinalen komt integratie van OTS en ANS er nog bij, en deze extra
stap zou voor sommige kinderen net te belastend kunnen zijn. Voor
kinderen die Engels leren is de uitdaging nog weer groter, want binnen de
OTS-grenzen zullen ze geen regelmaat in de rangtelwoorden kunnen
ontdekken. De evidentie voor de Engelse regel voor rangtelwoorden komt
pas later in de rij, wat betekent dat deze kinderen al geoefende
kernkenniskoppelaars moeten zijn om die evidentie te kunnen gebruiken.
Er is bij hen dus geen extra belasting bij hogere ordinalen zichtbaar, want
die moeten ze al aankunnen om überhaupt rangtelwoorden te kunnen
begrijpen. Dit punt werk ik in Hoofdstuk IV en V verder uit.

In het slothoofdstuk, Hoofdstuk V, bespreek ik niet alleen waarom
kinderen gebruikmaken van een regel om rangtelwoorden te leren, maar
ook waarom de verwerving van ordinale morfologie fundamenteel
verschilt van de verwerving van bijvoorbeeld verledentijdsvormen. Die
eerste vraag is relatief eenvoudig te beantwoorden: het is economischer om
een regel in te zetten dan om al die ordinalenlexicaal te leren. Uit de
literatuur blijkt dat het al ontzettend moeilijk is om hoofdtelwoorden te
leren, en die komen veel vaker voor dan rangtelwoorden. Ik stel daarom
dat kinderen liever gebruikmaken van kennis die ze al hebben om
rangtelwoorden ‘uit te rekenen’, dan dat ze dat moeizame lexicale proces
nog eens doorlopen. Door de lexicale kennis van hoofdtelwoorden te
combineren met morfosyntactische kennis (congruentie, nominale
modificatie, het ordinale suffix), kunnen kinderen de opslagroute dus
vermijden. Kinderen zijn dan gebaat bij een transparante relatie tussen
een rang- en een hoofdtelwoord, want dat helpt ze om rangtelwoorden als
geleed te herkennen en (tijdelijk) in de koelkast van het lexicon te
plaatsen, tot ze voldoende bruikbare evidentie hebben voor de regel. Door
middel van regels, via de delen, kunnen ze vervolgens achter de betekenis
van een rangtelwoord als geheel komen. Hoofdtelwoorden zijn dus een
product van opgeslagen kennis, terwijl rangtelwoorden voortkomen uit
(voornamelijk) regelkennis.

Deze regelkennis komt echter wel op een nogal ongebruikelijke
manier tot stand. In de literatuur wordt namelijk doorgaans aangenomen
dat regels pas productief worden na een opslagfase. Kinderen slaan een
vorm als waste bijvoorbeeld eerst ongeleed op, voordat ze de interne
geleding doorgrenzen en de vorm opsplitsen in de stam was en de uitgang
Onregelmatige vormen zoals liep en at worden ook opgeslagen, maar als
een kind de regel heeft ontdekt, kan er een zogenaamde U-curve ontstaan.
Het kind overgeneraliseert dan tijdelijk de regel, en zegt dus soms *loopte
of *ette hoewel hij eerder altijd correct liep of at produceerde. Als hetzelfde patroon voor rangtelwoorden zou gelden, dan zouden we verwachten dat kinderen derde begrijpen en produceren voordat ze *driede zeggen, maar we zien dat de productie van *driede juist samengaat met begripsproblemen bij derde. We zien dus meer een soort “J-curve”, waar er vóór de regel zo goed als niks is: geen begrip, geen productie, en geen bruikbare lexicale kennis, totdat de ordinale regel productief is. Bovendien suggereren de plotselinge sprongen in de ontwikkeling van zowel regelmatige als onregelmatige vormen dat rangtelwoordverwerving waarschijnlijk niet met een vertrouwde opslagfase begint.

De conclusie is dus dat schijnt bedriegt: rangtelwoordverwerving is niet zo voor de hand liggend als het misschien lijkt. Dit proefschrift levert daarom op twee manieren een betekenisvolle bijdrage. De meest concrete is de beschrijving van het ontwikkelingspatroon in (1) hieronder (zie ook Hoofdstuk V).

(1) Stadia in rangtelwoordverwerving

(i) Met behulp van aanwijzingen in de morfosyntaxis (zoals het feit dat rangtelwoorden voorkomen bij nomina in het enkelvoud, en hoofdtelwoorden juist bij meervoud) ontdekken kinderen dat rangtelwoorden naar individuen verwijzen, en niet naar sets. Als ze bijvoorbeeld om de vierde beer worden gevraagd, zullen ze misschien niet de juiste beer pakken, maar wel het juiste aantal beren: één.

(ii) Kinderen verwerven, als ze minimaal een 4-kenner zijn, eerst eerste. Deze vorm wordt om drie redenen relatief vroeg verworven: deze vereist geen telvaardigheid, komt ongeveer 50% meer voor dan tweede tot en met twintigste bij elkaar, en is strikt genomen geen rangtelwoord, maar de (regelmatige) superlatieve vorm van eer en eerder (Barbiers 2007). Dergelijke vormen worden relatief vroeg verworven (cf. Syrett 2016).

(iii) Hierna verwerven kinderen de rangtelwoordvormingsregel (informeel: hoofdtelwoord + suffix = rangtelwoord). In dit stadium begrijpen kinderen in elk geval lage, regelmatige rangtelwoorden, mits deze lage ordinalen voldoende evidentie leveren voor de regel, zoals in het Nederlands het geval is. Als er voor die regel ook hogere rangtelwoorden nodig zijn zouden CP-kenners zowel lage als hoge rangtelwoorden moeten begrijpen.
Om hoge rangtelwoorden te begrijpen moeten kinderen per definitie CP-kenner zijn, omdat we van kinderen die geen hoofdtelwoorden boven de vier begrijpen, niet kunnen verwachten dat ze rangtelwoorden na vierde begrijpen. Hoge rangtelwoorden kunnen bij CP-kenners nog wel problemen geven omdat de teltaak meer van het kind vraagt (verder tellen vergt meer inspanning, concentratie, etc.) maar ook omdat het conceptueel meer vraagt: beide kernkennisystemen (OTS en ANS) moeten worden gekoppeld voordat de regel kan worden toegepast. Die integratie is niet per se nodig voor lage ordinalen binnen het OTS-domein.

Onregelmatige rangtelwoorden worden na de regel verworven (zoals bij derde in zowel begrip als productie, en achtste in productie). Dit hoeft niet in alle talen samen te hangen met de beheersing van hoge ordinalen.

De tweede bijdrage is algemener: de data in dit proefschrift laten zien hoe belangrijk het kan zijn om een probleem van verschillende kanten te bekijken. Zo veranderde elk van de verschillende vergelijkingen (tussen begrip en productie, tussen analytische en synthetisch vormen, en tussen het Engels en het Nederlands) het beeld van rangtelwoorderverwerving een beetje. Bovendien blijkt pas bij het combineren van al die inzichten hoe verrassend dit ogenschijnlijk vanzelfsprekende patroon daadwerkelijk is. Die eerste, intuïtieve reactie (maar natuurlijk!) blijkt terecht, maar wel per ongeluk.
Caitlin was born on May 4th, 1988 in Red Bank, New Jersey and has been in the Netherlands since 1997. When she was ten, she wanted to be a teacher, a writer and a researcher. Twenty years later, she has written for regional newspapers in Kennemerland, taught Dutch (De Haagse Hogeschool) and linguistics (University of Amsterdam), freelanced as an editor and proofreader for academics, and completed a dissertation (this one).

Admittedly, her ten-year-old self thought research involved lab coats and Erlenmeyers, but she gradually learned that this is not necessarily the case. She graduated from the Gymnasium Felisenum (2006), moved on to the University of Amsterdam, and then never really left. She studied Language and Communication (2006–2009) as an undergraduate, during which time she minored in language development and variation, interned at the Meertens Institute and fell in love with linguistics. An MA in Dutch Language and Culture (2010) and a research MA in Linguistics (2012, cum laude), prepared her for her doctoral work, which she started in 2013 within the NWO Horizon Knowledge & Culture program. A research stay at the University of Maryland (2016) was part of this project. She has presented her work orally in 21 cities in 12 countries, and of course in written form, most of which is bundled here.