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Contents

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<i>General preface</i>	ix
<i>Acknowledgments</i>	x
<i>Abbreviations</i>	xvi
 1 Overview	 1
1.1 Introduction	1
1.2 The central metaphor	4
1.3 Overview of things to come	6
1.4 Ways to read this book	8
 2 The stage	 10
2.1 Introduction	10
2.2 Notational conventions	11
2.3 Mereology	11
2.3.1 Foundations of algebraic semantics	12
2.3.2 Axiomatizations of classical mereology	16
2.3.3 Mereology vs. set theory	18
2.3.4 Algebraic closure, atomicity, and groups	19
2.3.5 Higher-order properties	23
2.4 Ontology	23
2.4.1 Ordinary objects (type e)	25
2.4.2 Kinds (type e)	26
2.4.3 Events (type v)	27
2.4.4 Intervals (type i)	28
2.4.5 Degrees (type d)	29
2.4.6 Numbers (type n)	32
2.5 Functions	32
2.5.1 Thematic roles (type $\langle v, e \rangle$)	33
2.5.2 Trace functions: runtime and location (type $\langle v, i \rangle$)	35
2.5.3 Measure functions (types $\langle e, d \rangle$ and $\langle v, d \rangle$)	37
2.5.4 Unit functions (types $\langle d, n \rangle$ and $\langle i, n \rangle$)	38
2.5.5 The cardinality function (type $\langle e, n \rangle$)	40
2.6 Nouns	42
2.6.1 Singular count nouns	42
2.6.2 Plural count nouns	43
2.6.3 Measure nouns	46



5.3 Previous accounts of the minimal-parts problem	104
5.3.1 Dowty (1979)	104
5.3.2 Hinrichs (1985)	105
5.3.3 Moltmann (1989, 1991)	107
5.3.4 Link (1991b)	108
5.3.5 Borik (2006)	109
5.3.6 Summing up	110
5.4 Stratified reference as a solution to the minimal-parts problem	110
5.5 Summary	116
6 Aspect and space	117
6.1 Introduction	117
6.2 Subregions versus strata	121
6.3 Implementations of both approaches	125
6.3.1 Dowty (1979) and my proposal	125
6.3.2 Krifka (1998)	128
6.4 Comparing the approaches	129
6.4.1 The subregion-based approach	131
6.4.2 The strata-based approach	135
6.5 Summary	137
7 Measure functions	139
7.1 Introduction	139
7.2 Constraints on measure functions	140
7.3 Previous accounts	141
7.4 Strata theory and measurement	145
7.5 Summary	153
8 Covert distributivity	155
8.1 Introduction	155
8.2 Atomic distributivity	160
8.3 Nonatomic distributivity	163
8.4 Reformulating the D and Part operators	171
8.5 Previous work on event-based distributivity operators	175
8.6 The scopal behavior of <i>for</i> -adverbials	179
8.7 Summary	191
9 Overt distributivity	193
9.1 Introduction	193
9.2 Overt distributivity across languages	196
9.3 Relating overt and covert distributivity	209

9.4	Some more complicated cases	217
9.4.1	<i>Each</i> as a PP modifier	217
9.4.2	<i>Jeweils</i> distributing over a conjunction of verbs	218
9.4.3	<i>Jeweils</i> in subject position	220
9.4.4	Reverse DP-internal distributivity	222
9.5	Distributive determiners	224
9.6	Zimmermann's generalization explained	230
9.7	Previous work: Zimmermann (2002b)	233
9.8	Summary	236
10	Collectivity and cumulativity	239
10.1	Introduction	239
10.2	<i>All</i> and maximality	241
10.3	<i>Numerous</i> -type predicates	243
10.4	<i>Gather</i> -type predicates	245
10.5	Why <i>all</i> distinguishes between <i>numerous</i> and <i>gather</i>	250
10.6	Meaning shift effects triggered by <i>all</i>	254
10.7	From <i>all</i> to <i>each</i> : different granularity levels	258
10.8	<i>For</i> and <i>all</i> block cumulative readings	260
10.9	Open problems	265
10.10	Summary	267
11	Conclusion	269
11.1	Chapter-by-chapter summary	269
11.2	Future work	275
	<i>Appendix: Distributivity operators as repair strategies</i>	280
	<i>References</i>	283
	<i>Index of languages</i>	305
	<i>Index of people</i>	306
	<i>Index of topics</i>	310

Acknowledgments

This book is a substantially revised and extended version of my dissertation, Champollion (2010b), which introduced the framework of strata theory centered around the notion of stratified reference. It incorporates subsequent work as described here.

The story of this work begins in the summer of 2008. I had been a graduate student at the University of Pennsylvania for four years, and I was just about to finish a summer internship at the Palo Alto Research Center (PARC). Partly due to its proximity to Stanford University and Silicon Valley, PARC was a great place to do research at the intersection of linguistics and computer science. Among other things, I had been trying to hack some notion of aspect into the natural-language semantic pipeline they were running at the time. I enjoyed this task: I could feel like the real computational linguist that part of me has always wanted to be, and still read semantics papers all day long. Then my supervisors, Cleo Condoravdi and Danny Bobrow, asked me if I wanted to move to the West Coast and turn my aspect project into a dissertation there. None of us knew back then what it would be about and how much computer science there would be in it. In the end, there is none in it at all. I'm deeply grateful to Cleo and Danny for the trust and enthusiasm with which they embarked on this project with me.

Cleo was the natural choice as my dissertation advisor, and I haven't regretted that choice a single time. Perhaps most importantly for me, she left me the freedom to take this enterprise in whatever direction I wanted. This is not to say that she was ever uninterested or not fully engaged, despite her many responsibilities at PARC. Cleo kept offering patient encouragement throughout the many unexpected turns this work took, and she always had the right amount of clear advice at the right time. She introduced me to the PARC and Stanford communities and, over the course of numerous hiking trips, also to the beauty of the Bay Area.

I'm deeply grateful to the chair of my dissertation, Aravind Joshi. He has been unerringly supportive as he sponsored my first stay at Penn as an exchange student, and later on as I found my way through graduate school between formal language theory and formal semantics. He selflessly supported my decision to move away from Penn and from his own research agenda.

The other members of my dissertation committee were Maribel Romero and Florian Schwarz. Maribel drew me right into semantics from the very first class I took with her at Penn in 2004. Her classes were the best I ever took. Her approach to semantics might well shape my own work more than I know. Like everyone else, I looked on in amazement as she changed jobs, moved across the ocean to Konstanz, founded a family, became department chair, and kept an eye on my dissertation all at once. I am grateful to her for her generous help. There's no way to sneak a flawed linguistic

argument past her, though I'm sure this book contains many that she has long given up on trying to correct.

Although Florian Schwarz joined Penn and the committee only shortly before the dissertation was completed, he worked his way into the project with remarkable speed and made an impact on it, especially by challenging the way I originally characterized stratified-reference constraints as presuppositions. I thank him for numerous detailed comments and for his enthusiastic approach to the enterprise. It was a great pleasure to have him on the committee.

Tony Kroch served on the dissertation committee for a good year or so. I'm grateful that he did, and I'm glad he stayed around even after he officially left. I thank him for giving me the benefit of the doubt early on, for encouraging me to be bold, and for not thinking that his efforts were lost on me. Tony never made a secret of his opinion when he thought I was headed the wrong way, and given my personality, I think he deserves credit for that.

I have a lot of people to thank for teaching me linguistics, engaging with my ideas, and making sure that writing the dissertation and this book was not a lonely business. It would be impossible to thank everyone, and if you feel unjustly omitted from what follows, you most likely are.

The late Ellen Prince took me seriously when I was still wet behind the ears, and I hear she put in a good word for me when I wanted to join Penn. I regret not having spent more time with her.

My Master's degree advisor, Mitch Marcus, has been supportive throughout my time at Penn, and it is largely thanks to his and Aravind's efforts that I could navigate the gap between linguistics and computer science.

I am grateful to my fellow graduate students at Penn from 2004 to 2010, particularly Aviad Eilam, Keelan Evanini, Eva Florencio Nieto, Jonathan Gress-Wright, Catherine Lai, Lucy Lee, Laia Mayol, Jean-François Mondon, and Josh Tauberer. They plowed through the endless coursework with me, endured my island violations, and never lost patience with my unending hunger for grammaticality judgments. It's been great living with my linguist roommates Ariel Diertani, Jonathan Gress-Wright, Laurel MacKenzie (now my colleague at NYU), Laia Mayol, and Satoshi Nambu at 4400 Spruce St. I especially thank Satoshi for helping me print and submit the dissertation while I was in Europe. I thank Yanyan Sui for being who she is, for giving me a glimpse of Chinese, and for showing me the many ways to open an orange. Jeeyoung Kim, Angela Lee, and her Highness Leslie Williams of Sansom Place helped me get away from linguistics once in a while and made sure I didn't take myself too seriously.

I am grateful to the faculty and administrators at the linguistics department at Penn, particularly to Gene Buckley and Amy Forsyth, for their support and for making it possible for me to spend time at PARC and Stanford. I also thank Penn for supporting me through a Benjamin Franklin fellowship, a Dissertation Completion fellowship, and various travel grants.

that I occasionally used to confirm (or in one case, as described four paragraphs ahead, to disconfirm) assumptions I had made in 2010 about the meaning and acceptability of various sentences. In this connection, I thank Michael Yoshitaka Erlewine and Hadas Kotek for providing the open-source software package *Turktools* to the semantics community (Erlewine & Kotek 2016).

I have benefited from many discussions in graduate seminars about this work that I taught at NYU in 2013 and 2014, and in summer school courses that I taught at ESSLI 2012 and at the 2015 LSA summer institute. Teaching these courses was incredibly inspiring, and I am very grateful to the students who took part in them. Some of the changes in this book originated in discussions in these courses. I owe special thanks to Jeremy Kuhn, who took part in the second NYU seminar and who subsequently presented his work on the word *all* as Kuhn (2014). Jeremy's influence is reflected and acknowledged throughout Chapter 10.

I published an overview of strata theory as a target article in the open peer review journal *Theoretical Linguistics* (Champollion 2015c). I thank Manfred Krifka for encouraging me to write that article, and I am indebted to him and to Hans-Martin Gärtner for their help as editors. I am grateful to the authors of the responses to that article (Corver 2015, Doetjes 2015, Link 2015, Piñón 2015, Schwarzschild 2015, Syrett 2015). These responses prompted me to introduce a number of refinements to the theory, as described in detail in my reply article (Champollion 2015b). This book has been updated to reflect these refinements.

A precursor of Chapter 4 was published as Champollion (2009). Two handbook articles, Champollion (to appear) and Champollion & Krifka (2016), are based in part on the dissertation. While preparing them, I have drawn primarily on the background material in Chapters 2 and 4. This has led to revisions to the text, some of which I have incorporated back into this book. The presentation in Chapter 7 draws in part on section 4 of Champollion (2015b) and on section 3 of Champollion (2015c).

Chapters 1, 2, 3, 4, 6, and 7 have been only lightly changed, mostly to improve presentation. Chapter 5 has been partly rewritten. I have removed discussion of frequency adverbs that was tangential to its main subject, and of a generalization (labeled the “sufficiently-many events” observation) based on subtle gradient judgments that I have since then tried and failed to reproduce experimentally in collaboration with Hanna Muller and Linmin Zhang. I have also expanded the section describing my account.

Chapter 8 has undergone significant expansion and changes compared with the dissertation, leading to its publication as an article in the open-access journal *Semantics and Pragmatics* (Champollion 2016a), which is reprinted here with slight modifications. A closely related proceedings paper, Champollion (2013), is not included in this book, but its contents are referenced at the appropriate places.

Chapter 9 is based on work I carried out at the University of Tübingen and at NYU after the dissertation was completed. Its main ideas have appeared as a short proceedings paper (Champollion 2012). Just like the previous one, this chapter has

been published in its current form as a *Semantics and Pragmatics* article (Champollion 2016c) and is reprinted here with slight modifications. For their help with the text of Chapters 8 and 9, I am grateful to the journal editors, particularly Kai von Fintel and Kjell Johan Sæbø, and to the journal reviewers, particularly Malte Zimmermann.

Chapter 10 is based on Chapter 9 of the dissertation. It has undergone substantial revisions and expansions, described in the main text. A part of this chapter overlaps with Champollion (2015c); another part has appeared as a short proceedings paper, Champollion (2016b). Significant parts of the chapter are new and not included anywhere else. The original chapter contained an extensive discussion of dependent plurals, most of which has been cut from this book because it is only marginally related to strata theory.

Chapter 11, the conclusion, has been rewritten from scratch and substantially expanded to include a chapter-by-chapter summary of the book. Some of the suggestions for future work have previously appeared in Champollion (2015c).

Over the last eight years, many linguists have taken the time to converse or correspond with me about various aspects of this book. Many thanks to Alan Bale, Justin Bledin, Adrian Brasoveanu, Benjamin Bruening, Dylan Bumford, Seth Cable, Gennaro Chierchia, Ivano Ciardelli, Chris Collins, Ashwini Deo, Carmen Dobrovie-Sorin, Jean Mark Gawron, Justyna Grudzinska, Zsófia Gyarmathy, Robert Henderson, Petra Hendriks, Paul Hovda, Sonia Kasyanenko, Chris Kennedy, Manuel Križ, Manfred Krifka, Daniel Lassiter, Chris LaTerza, Lisa Matthewson, Jon Ander Mendia, Alice ter Meulen, Friederike Moltmann, Oleg Neroslavsky, David Nicolas, Hazel Pearson, Maria Mercedes Piñango, Chris Piñón, Jim Pryor, Adam Przepiórkowski, Floris Roelofsen, Uli Sauerland, Remko Scha (†), Roger Schwarzschild, Chung-chieh Shan, Alexander Williams, Yoad Winter, Kata Wohlmuth, Linmin Zhang, Ziren Zhou, Thomas Ede Zimmermann, and Eytan Zweig. Likewise, I thank audiences at the 2009 workshop on Construction of Meaning at Stanford, at the 2009 CHRONOS conference on tense, aspect, and modality in Paris, at the 2010 Penn Linguistics Colloquium, at the 2011 workshop on distributivity in Stuttgart, at the 2011 Amsterdam Colloquium, at the 2013 conference on Semantics and Linguistic Theory at UC Santa Cruz, at the 2014 Cornell workshop in linguistics and philosophy, at the 2015 North Eastern Linguistic Society conference at Concordia University, at the ZAS Berlin, and at the Universities of Connecticut, Dublin (Trinity College), Frankfurt, Göttingen, Konstanz, Los Angeles (UCLA), Maryland, Munich (Center for Mathematical Philosophy), Paris 7, Potsdam, Toruń, Tübingen, Utrecht, Warsaw, and Yale, for their feedback.

For native speaker judgments, I thank Meike Baumann, Renée Blake, Isaac Bleaman, Heather Burnett, WooJin Chung, Ivano Ciardelli, Chris Collins, Liz Coppock, Masha Esipova, Hana Filip, Stephanie Harves, Daði Hafþór Helgason, Hildur Hrólfsdóttir, Gianina Iordăchioaia, Zack Jagers, Sonia Kasyanenko, Mike Kennedy, Songhee Kim, Sverrir Kristinsson, Jeremy Kuhn, Chigusa Kurumada, Luciana

Meinking Guimarães, Yohei Oseki, Roumyana Pancheva, Adam Przepiórkowski, Leonor Remédio, Floris Roelofsen, Bujar Rushiti, Kjell Johan Sæbø, Todd Snider, and Gunnar Ingi Valdimarsson.

At Oxford University Press, I thank Lisa Eaton, Julia Steer, and Vicki Sunter for their help throughout the process, as well as the series editors, David Adger and Hagit Borer. I am grateful for the detailed reviews of the manuscript by Stefan Hinterwimmer and by an anonymous reviewer. I have benefited from them while preparing this book.

I have also greatly benefited from Vera Hohaus' many knowledgeable comments on Chapters 1 through 7, and from Sarah Barrett's, Anna Howell's, Ian Pickett's, and Todd Snider's careful proofreading of the entire manuscript at various stages. I thank Vera Zu for her help with the bibliography, and Philip Shushurin for preparing the index. I gratefully acknowledge a Grant-in-Aid by the NYU Center for the Humanities in support of the publication of this book. I also thank Scott Collard, Jill Conte, April Hathcock, Monica McCormick, and Michael Stoller at the NYU libraries for assisting me in the publishing process.

For their hospitality and much more over the last eight years as this work took me around the world, I'm grateful to many friends of mine: in Philadelphia, Julia Deák, Aviad Eilam, Catherine Lai, and Michela Tincani; in Austin, Liz Coppock; in Berlin, Uli Sauerland and Kazuko Yatsushiro; in Paris, Catherine Collin and my aunts and uncles from the Champollion family, Elisabeth, Ginou, and Hervé; in Portland, Svetlana Antonyuk-Yudina and Vadym Yudin; in Vienna, Gregor and Monika Rot; in Tübingen, Anke and Frank Tochtermann; in Neuchâtel, Sveta Krasikova and Ventsislav Zhechev; in Amsterdam, Galit and Adar Weidman Sassoon; in Warsaw, Justyna Grudzinska; in Moscow, Nadia Antonova, Petya Volyak, Masha Tsyurupa, Nick Gribakin, Natasha Korotkova, Vanya Kapitonov, and Ania Grashchenkova. At an early stage in the development of this project, Arnim von Stechow provided generous advice and a chance to take a step back and examine my ideas from the ultimate bird's-eye perspective, in his mountain hut high up in the snow-covered Swiss alps.

And most of all: meine Mutter, mon père, Tuğbacım. I don't know how to thank you. But still: thank you.

1

Overview

The central claim of this book is that a unified theory of distributivity, aspect, and measurement for natural language is feasible and useful.

1.1 Introduction

I claim that a number of natural language phenomena from the domains of aspect,¹ plurality, cumulativity, distributivity, and measurement, which are currently treated by separate theories, are in fact intimately related. Previous accounts of these phenomena either fail to generalize appropriately, or live on as limiting cases of a system presented here under the name of *strata theory*. This system is not a radical reorientation of the grammar. By subsuming and building on previous characterizations, strata theory retains much of what has been formerly gained, and provides a unified framework in which new correspondences are drawn between existing concepts.

The road to this claim starts with four semantic oppositions which are closely associated with the domains under consideration. These are the telic/atelic opposition, which is central to the study of aspect; the singular/plural opposition and the count/mass opposition, which are central to the study of plurality and measurement; and the collective/distributive opposition, which is central to the study of distributivity. These oppositions can be formally related to one another. This in itself is not a new insight. It has long been known that there are close parallels between the singular/plural and the count/mass opposition (e.g. Link 1983) and, likewise, between the count/mass and the telic/atelic opposition (e.g. Bach 1986). That these formal parallels can be extended to encompass the collective/distributive opposition has not been explicitly discussed as far as I know, but it is not difficult to do so.

The nature of the parallelism between all these oppositions can be described intuitively in terms of boundedness. Singular, telic, and collective predicates are

¹ “Aspect” is used in the literature to refer to many different things. Throughout this book, I use the term to refer to what has been variously called inner aspect, lexical aspect, temporal constitution, actionality, or aktionsart, as opposed to the phenomenon referred to as outer aspect, grammatical aspect, or viewpoint aspect. Broadly speaking, I understand inner aspect as referring to the telic/atelic opposition, and outer aspect as referring to the imperfective/perfective opposition. Outer aspect is not discussed in this book.

delimited or bounded in ways that plural, mass, atelic, and distributive predicates are not. Making formal sense of the parallelism therefore amounts to characterizing the difference between boundedness and unboundedness. How to do this is one of the central questions which strata theory proposes to answer. I call it the *boundedness question*.

Answering the boundedness question amounts to specifying what it means for a predicate to be atelic, distributive, plural, or to have mass reference. It is not obvious that there should be a single property that is shared by all these predicates. As this book shows, however, it is indeed possible to isolate such a property. The identity of this property can be determined by analyzing a number of nominal and verbal constructions which have one thing in common: each is sensitive to one of the semantic oppositions listed above. These constructions are *for*-adverbials, which distinguish atelic from telic predicates, as in (1); pseudopartitives, which distinguish plurals and mass nouns from singular count nouns, as in (2); and adverbial *each*, which distinguishes distributive from collective predicates, as in (3). I refer to them collectively as *distributive constructions*.

- | | | |
|-----|--|---------------------|
| (1) | a. John ran for five minutes. | <i>atelic</i> |
| | b. *John ran to the store for five minutes. | * <i>telic</i> |
| (2) | a. thirty pounds of books | <i>plural</i> |
| | b. thirty liters of water | <i>mass</i> |
| | c. *thirty pounds of book | * <i>singular</i> |
| (3) | a. The boys each walked . | <i>distributive</i> |
| | b. *The boys each met . | * <i>collective</i> |

These three constructions form the empirical basis of this book. However, they probably represent only a small sample of distributive constructions. For example, true partitives and comparative determiners accept the same classes of nouns and of measure functions as pseudopartitives do (Schwarzschild 2006). For present purposes, it is enough to focus on the three distributive constructions in (1) through (3), firstly, because they cut across the domains of distributivity, aspect, and measurement, and secondly because each of them is regarded as central to its domain in the sense that any theory of it must account for its behavior. More concretely, *for*-adverbials are regarded as the prime diagnostic of atelicity (Verkuyl 1989); *each* is the standard example of a distributive item (Link 1987b); and pseudopartitives are arguably the most prominent place in which natural language shows its sensitivity to formal properties of measurement (Krifka 1998, Schwarzschild 2006).

The novel angle of this book consists in considering the constructions in (1) through (3) as parts of a whole. Previous work has produced separate theories to account for the behavior of each of these constructions and for the phenomena that they exemplify. The resulting theories are often more limited in scope than they could be. For example,

work on distributivity has focused on how best to formalize distributive readings, rather than on extending the notion of distributivity. Likewise, the study of aspect has concentrated entirely on temporal phenomena, and the study of measurement in natural language has focused largely on mass terms, partitives, and comparatives. This development has obscured the view on the common properties of these constructions. However, this problem is not inherent in the approaches encoded in these theories. Once the connection between distributivity, aspect, and measurement is made formally explicit, it is easy to connect many existing theories to each other, and to extend them to domains beyond the ones in which they have traditionally been applied. One can then combine the strengths of each account, and synthesize them to extend their empirical coverage. This is the motivation behind this book.

The presence of distributive constructions in every one of the domains of interest makes it possible to place strata theory on a solid empirical foundation, because these constructions allow us to operationalize the boundedness question. Instead of asking abstractly what it is that atelic and distributive and mass and plural predicates have in common with each other, we can search for the property that the bold constituents in the acceptable examples in (1a), (2a), (2b), and (3a) have in common, to the exclusion of the unacceptable examples in (1b), (2c), and (3b).

In order to express generalizations over distributive constructions, I will deploy a common terminology. As is explained in more detail in Chapter 4, *Share* refers to the constituent whose denotation is distributed over the parts of the referent of the other constituent, which is called the *Key*. For example, (1a) distributes *ran* (*Share*) over *five minutes* (*Key*); (2b) distributes *water* (*Share*) over *thirty liters* (*Key*); and (3a) distributes *walk* (*Share*) over *the boys* (*Key*). I assume that these components are related by certain functions such as the function *runtime* in (1a), the function *volume* in (2b), and the thematic role *agent* in (3a). I use the term *Map* for these functions, since they always map entities (such as events or substances) associated with the *Share* to entities (such as intervals, degrees, or individuals) associated with the *Key*. These terms and relationships are illustrated in Table 1.1.

This approach results in new takes on a large and diverse number of linguistic phenomena, which are brought together here for the first time in one and the same theoretical picture.

TABLE 1.1. A bridge from distributivity to aspect and measurement

Construction	Example	Key	Share	Map
Adverbial <i>each</i>	The boys each walked	the boys	walk	agent
For-adverbial	John ran for five minutes	five minutes	John ran	runtime
Pseudopartitive	thirty liters of water	thirty liters	water	volume

The rest of this chapter outlines the intuition behind strata theory (Section 1.2), gives a brief overview of the contents of the rest of the book (Section 1.3), and closes with a set of suggestions regarding the different ways in which readers could navigate through the book (Section 1.4).

1.2 The central metaphor

The guiding idea behind this book is that the constructions illustrated in (1) through (3) exclude bounded predicates through a parametrized constraint which is introduced into distributive constructions through certain words such as *for*, *of*, and *each*. This constraint is formulated in terms of a higher-order property, *stratified reference*. This property requires a predicate that holds of a certain entity or event to also hold of its parts along a certain dimension and down to a certain granularity. Dimension and granularity are understood as parameters which distributive constructions can set to different values.

The dimension parameter specifies the way in which the predicate in question is distributed. Different settings of this parameter allow one and the same predicate to be atelic but not distributive, or vice versa. When the dimension parameter is set to time, stratified reference applies to atelic predicates, as in (1). When it is set to a measure function like weight or volume, stratified reference applies to mass and plural predicates, as in (2). When it is set to a thematic role like agent, stratified reference applies to distributive predicates, as in (3).

The granularity parameter specifies that the parts in question must be either atomic or simply smaller in size than the whole, as measured along the dimension. This parameter accounts for the differences between distributive constructions over discrete (count) domains, such as adverbial-*each* constructions, and those over domains involving continuous dimensions, such as *for*-adverbials and pseudopartitives.

The names *dimension*, *granularity*, and *stratified reference* are derived from a visual metaphor, which I develop here. Let me stress that I use this metaphor only for the purpose of conveying the intuitions behind strata theory. It does not have any formal status, it does not occur in the formulation of the theory, and it is not claimed to have any psychological or cognitive reality—unlike, for example, the diagrams in the cognitive grammar literature (Langacker 1986).

The metaphor is based on the idea that individuals, substances, and events occupy regions in an abstract space. The dimensions of this space include the familiar spatial and temporal dimensions as well as any measure functions and thematic roles that happen to be defined for the entity. (To understand a thematic role as a dimension, we assume that the individuals that correspond to these roles are ordered in an arbitrary but fixed canonical order, such as the alphabetical order given by their first and last names.) An object whose weight is large corresponds to a region with a large extent along the weight dimension. An event whose agent is a plural entity corresponds to

a region with a large extent along the agent dimension, while an event whose agent is singular corresponds to a region which is not extended along the agent dimension at all. A temporally and spatially punctual event whose thematic roles are all singular entities corresponds to a point. A temporally and spatially punctual event that has plural entities as its agent and theme corresponds to an infinitely thin rectangle that is extended along the agent and theme dimensions.

Consider the old intuition that any atelic predicate has the subinterval property (Bennett & Partee 1972). This property says that whenever a predicate holds at an interval t , it also holds at every subinterval of t , all the way down to instants. Put in event-semantic terms, a predicate like *run* is atelic because we can “zoom in” to any temporal part of a running event to find another running event. We cannot do that with a telic predicate like *run to the store*, because any temporal part of an event of running to the store that does not include the end point (the store) does not itself qualify as running to the store. In the metaphor, the subinterval property translates to the following picture: any event in the denotation of a predicate that has the subinterval property can be divided into infinitely thin layers that run perpendicular to the time dimension and that are also in the denotation of this atelic predicate. This gives rise to the well-known “minimal-parts problem”: strictly speaking, there are no instantaneous running events, for example. If the subinterval property is to have any viable chance, it must therefore be amended so that the event layers are constrained to be thinner than the whole event, but do not have to be infinitely thin. Formally, this effect is achieved by adding a granularity parameter to the subinterval property. I call these layers *strata*. This name is chosen to remind the reader of geological strata, the layers of rock which can be observed in geological formations in places such as the Grand Canyon. A geological stratum can be just a few inches thick (though not infinitely thin) and extend over hundreds of thousands of square miles. This aspect is mirrored in the theory, where strata are constrained to be thin along one dimension, but may be arbitrarily large as measured in any other dimension.

The metaphor I have used to describe the subinterval property involves layers or strata rather than points or pebbles, because the subinterval property does not constrain any dimensions other than time. This feature is not accidental. While the relevant parts of running events must be short, or thin, in the temporal dimension, they may have plural entities as agents or themes, they may be extended in space, and so on. This view leads to a natural generalization. Normally, geological strata are horizontal, but due to geological movement, they can also be oriented along another dimension. For example, they can run vertically. Similarly, I have introduced the concept of temporal strata as resulting from dividing an event along the temporal dimension, but we can also imagine spatial or “agental” strata—subevents that are constrained based on their spatial extent or based on their number of agents. Once this step is taken, the atelic/telic opposition can be related to the collective/distributive opposition in a Neo-Davidsonian setting. Distributive predicates require any event in

their denotation to be divisible into strata that are constrained to have atomic thickness on the dimension of the appropriate thematic role. For example, any plural event in the denotation of a predicate like *smile* or *read a book* must be divisible into strata that have atomic agents and that belong to the denotation of the same predicate. Lexical predicates like *smile* have this property due to world knowledge, and phrasal predicates like *read a book* can acquire it through a modified version of the distributivity operators known from Link (1987b) and Schwarzschild (1996). Collective predicates like *be numerous* do not satisfy stratified reference on the thematic role of their subjects, because their subjects can be plural entities whose parts are not themselves numerous.

1.3 Overview of things to come

This section briefly previews the contents of the remaining chapters of the book. A more extended summary is found in Chapter 11. Section 1.4 offers a set of suggestions regarding the different ways in which readers can navigate through the book.

Chapter 2, “The stage,” presents a distilled picture of the crucial issues in the theoretical background assumptions, and develops the framework on which strata theory is built. This framework is essentially a synthesis of the work by Lønning (1987), Link (1998a), Krifka (1998), Landman (2000), and others. Its mathematical foundation is classical extensional mereology, which is presented and discussed at length. The overview in this chapter is intended as a reference point for future researchers and spells out the relevant background assumptions as explicitly as possible, especially in the case of choice points where the literature has not yet reached consensus on a preferred analysis. Issues discussed in this chapter include the meaning of the plural morpheme, the question whether the meanings of verbs are inherently pluralized, the formal properties of thematic roles, and the compositional process.

Chapter 3, “The cast of characters,” presents the three constructions listed in (1) through (3) (*for*-adverbials, pseudopartitives, and adverbial *each*) by means of some typical examples. Building on the foundations laid out in Chapter 2, this chapter develops a baseline theory for the syntax and semantics of these constructions and their constituents, keeping things symmetric across domains as much as seems reasonable so that the parallels drawn in subsequent chapters are not obscured more than necessary. The chapter discusses various properties of these constructions, and introduces simplified Logical Forms for them that provide a scaffold on which the theory in the rest of the book is built.

Chapter 4, “The theory,” presents stratified reference as an answer to the bound-ness question. The parallelism between the telic/atelic, collective/distributive, singular/plural, and count/mass oppositions is captured in a unified framework. After a brief overview of the empirical phenomena that have been discussed under the rubric of distributivity, the notion of stratified reference is gradually developed as a

generalized notion of distributivity. It is then used to formulate a single constraint that explains each of the judgments in (1) through (3), and to predict distributive entailments of lexical predicates via meaning postulates.

Chapter 5, “Minimal parts,” is about the minimal-parts problem: some eventualities and substances fail to distribute at very small scales because they have parts that are too small to satisfy certain mass terms and atelic predicates (Dowty 1979). Focusing on atelic predicates modified by *for*-adverbials, the chapter discusses some previous attempts to solve the problem before presenting a novel solution in detail. It is shown that stratified reference not only avoids problems that infinitely small parts cause for proposals based on the subinterval property and related notions, but also makes the right predictions as far as the interaction between the respective predicate and the length of the interval denoted by the complement of *for* is concerned.

Chapter 6, “Aspect and space,” models the relation between temporal aspect (*run for an hour* / **run all the way to the store for an hour*) and spatial aspect (*meander* / **end for a mile*) previously discussed by Gawron (2009). The chapter shows that *for*-adverbials impose analogous conditions on the spatial domain and on the temporal domain, and that an event may satisfy stratified reference with respect to one of the domains without satisfying it with respect to the other one as well. This provides the means to extend the telic/atelic opposition to the spatial domain. The chapter argues in some detail that stratified reference is in this respect empirically superior to an alternative view of telicity based on divisive reference (Krifka 1998).

Chapter 7, “Measure functions,” explains the linguistic relevance of the difference between extensive measure functions like volume and intensive measure functions like temperature, as illustrated by the pseudopartitives *thirty liters of water* vs. **thirty degrees Celsius of water* (Krifka 1998, Schwarzschild 2006). Subsuming these previous accounts, stratified reference correctly predicts the monotonicity constraint: such constructions disallow measure functions that generally return the same value on an entity and on its parts. For example, in order for **thirty degrees Celsius of water* to be acceptable, it would have to describe a water entity whose parts are colder than itself; but there are no such entities. Stratified reference relativizes unboundedness to just one dimension or measure function at a time. This makes it possible to account for examples like *five feet of snow* even though not every part of a five-foot layer of snow is less than five feet high.

Chapter 8, “Covert distributivity,” investigates and formalizes different sources of covert distributivity. Apart from lexical distributivity effects, which are modeled by meaning postulates, phrasal distributivity is captured via two operators: (i) a D operator distributing over atoms only (Link 1987), and (ii) a cover-based Part operator, which can also distribute over nonatomic pluralities under contextual licensing (Schwarzschild 1996). These operators are couched within strata theory and equipped with its granularity and dimension parameters. The granularity parameter captures

the difference between atomic and nonatomic distributivity. The dimension parameter makes an extension to the temporal domain possible, which explains why indefinites in the syntactic scope of *for*-adverbials tend not to covary (?*John found a flea on his dog for a month*, Zucchi & White 2001). The resulting theory surpasses accounts in which nonatomic distributivity is freely available, or not available at all; furthermore, it correctly predicts differences between lexical and phrasal nonatomic distributivity.

Chapter 9, “Overt distributivity,” explains the crosslinguistic semantic differences between distance-distributive items such as English *each* and German *jeweils* by treating them as overt versions of the atomic and the nonatomic distributivity operator respectively. The proposed analysis explains why *jeweils* can distribute over salient occasions and why this is never possible for *each* (Zimmermann 2002b). It also accounts for the fact that distributive determiners can take part in cumulative readings with items outside of their syntactic scope, and for their ability to interact with nondistributive event modifiers (Schein 1993, Kratzer 2000, Champollion 2010a).

Chapter 10, “Collectivity and cumulativity,” develops a theory of the word *all*. In some respects, such as its incompatibility with certain collective predicates like *be numerous* (Dowty 1987, Winter 2001) and its limited ability to take part in cumulative readings (Zweig 2009), this word is similar to distributive items like *every* and *each*. In other respects, such as its compatibility with collective predicates like *meet* and its ability to license dependent plurals, it differs from distributive items. This tension between the distributive and the nondistributive facets of *all* is resolved via stratified reference, which is used to formulate the semantics of *all* in terms of a subgroup distributivity requirement and to formulate meaning postulates for collective predicates like *meet* that give rise to distributive inferences to subgroups.

Chapter 11 concludes the book by summarizing its main insights and results. A detailed chapter-by-chapter summary provides a bird’s-eye view of strata theory and stratified reference. The summary highlights the conceptual and theoretical moves as well as their empirical payoff. It contrasts the property-based perspective on stratified reference introduced in Chapter 4 and developed in Chapters 5 through 7 with the operator-based perspective that is central to Chapters 8 and 9, and it sketches how both perspectives come into play in Chapter 10. The book concludes with a list of open problems and suggestions for further research, including a brief discussion of connections to other frameworks such as cognitive and conceptual semantics.

1.4 Ways to read this book

This book presupposes graduate-level knowledge of theories of formal semantics of natural language, as can be found in various textbooks such as Heim & Kratzer (1998). Although this book is self-contained, readers who are new to mereology and algebraic semantics may find it useful to consult the following handbook articles:

for an introduction to classical extensional mereology and an overview of algebraic semantics, Champollion & Krifka (2016); and for an empirical overview of distributivity along with collectivity and cumulativity, Champollion (to appear). These articles overlap in part with this book, but they go into more depth on certain issues, such as aspectual composition in the case of Champollion & Krifka (2016) and psycholinguistic findings as well as crosslinguistic facts in the case of Champollion (to appear).

Readers who are already familiar with these topics, or who are chiefly interested in the linguistic issues discussed in the book, may want to skip Chapter 2 and come back to it in order to clarify questions that come up as they read further.

Champollion (2015c), a target article, provides a self-contained overview of the theory in this book, and can be read as such, especially when taken together with some amendments to the theory described in the last section of the reply article, Champollion (2015b). The theory in this book has been updated to take these amendments into account.

Everyone unfamiliar with these papers who would like to understand just one or two parts of the book should start by reading Chapters 3 and 4; the chapters following these two are modular. Readers who are particularly interested in just one of the topics covered in this book—aspect, measurement, and distributivity—may find it useful to concentrate on the following parts: for aspect, Chapters 5 and 6, and Section 8.6; for measurement, Chapter 7; and for distributivity, Chapters 8, 9, and 10. The detailed chapter-by-chapter summary in Chapter 11 may be helpful as a way to get a bird's-eye perspective on the theoretical and empirical coverage of the book.

11

Conclusion

This chapter concludes the book by summarizing its main insights and results in a chapter-by-chapter summary (Section 11.1) and by offering some suggestions for further research (Section 11.2).

11.1 Chapter-by-chapter summary

In this book, I have developed a new approach to the semantics of distributivity, aspect, and measurement, three domains which are traditionally addressed by separate areas of research within formal semantics. By triangulating between these domains, I have arrived at a unifying perspective from which I made theoretical and empirical contributions to the study of the formal semantics of natural language.

My main theoretical contribution, introduced in **Chapter 1** and laid out throughout the book, is the notion of *stratified reference*, a concept that requires a predicate that applies to an entity—be it a substance, an event or a plural individual—to also apply to the parts into which this entity can be decomposed along some dimension and down to some level of granularity. The concept is general enough to subsume a wide range of previous proposals, yet formally precise enough to make testable predictions and to transfer insights across traditional boundaries. The resulting framework, *strata theory*, is intended as a bridge that spans a number of semantic oppositions: singular/plural, count/mass, telic/atelic, and collective/distributive. While it has often been observed that these semantic oppositions are similar, and proposals have been made to bring some of them under the same umbrella, this work is the first one to propose a fully unified account. Intuitively, the concept that underlies each of these oppositions is the difference between boundedness and unboundedness. Singular, count, telic, and collective predicates are all delimited or bounded, in ways that set them apart

from plural, mass, atelic, and distributive predicates. When it comes to formally describing what boundedness amounts to, characterizations in the semantic literature have tended to be limited to one domain: aspect, distributivity, or measurement only. Stratified reference provides a characterization that works in all of these domains. It builds on the same background assumptions as many previous theories and frameworks based on classical extensional mereology and algebraic semantics (Lønning 1987, Link 1998a, Krifka 1998, Landman 2000). These theories and assumptions are presented in explicit and distilled form in **Chapter 2**, with a focus on areas in which no consensus has been reached, such as the meaning of the plural morpheme, the question whether the meanings of verbs are inherently pluralized, the formal properties of thematic roles, and the compositional process. This chapter is intended as a reference point for future researchers and as an introduction to the relevant parts of the formal semantic literature.

My main empirical contribution is the observation that a large class of nominal and verbal constructions impose analogous unboundedness constraints on a predicate denoted by one of their constituents. A representative selection of what I have called *distributive constructions*—namely *for*-adverbials, pseudopartitives, and adverbial *each*—is described in **Chapter 3** and onwards. The chapter includes simplified Logical Forms for these constructions that provide a scaffold on which the theory in the rest of the book is built. Distributive constructions give us an empirical handle on the conceptual question of how to characterize unboundedness. For example, the fact that *for an hour* can modify the unbounded predicate *eat apples* but not the bounded predicate *eat thirty apples* makes it possible to constrain the space of options for formal definitions of unboundedness by studying the algebraic properties of these and related predicates (Krifka 1998). Stratified reference emerges from a systematic investigation of these constructions and of previous theories that account for their behavior within the framework of algebraic semantics.

Since unboundedness is a property of predicates, and since predicates are properties, it is natural to think of unboundedness as a higher-order property. Indeed, previous work in algebraic semantics has used higher-order properties such as cumulative or divisive reference to characterize different facets of unboundedness (Link 1998a, Krifka 1998, and others). Such properties are a useful stepping stone towards a formal characterization of unboundedness, but they

are too rigid to provide a nuanced understanding of the differences between these facets. For example, distributivity and atelicity can both be seen as facets of unboundedness; but one and the same predicate can be atelic without being distributive or vice versa, or distributive with respect to one thematic role but not another. **Chapter 4** presents stratified reference as a formalization of unboundedness and as a means to capture the parallels between the semantic oppositions in a uniform way. After giving a brief overview over the empirical phenomena that have been discussed under the rubric of distributivity, the notion of stratified reference is gradually developed as a generalized notion of distributivity. It is then used to formulate constraints that capture the behavior of distributive constructions and meaning postulates that predict distributive entailments of lexical predicates.

Two factors make it possible to identify a single formal property that describes unboundedness in all its facets. The first factor consists in using the same descriptive terms for constituents that behave analogously across syntactically and semantically distinct distributive constructions. The terms *Key* and *Share* from the literature on distributivity turn out useful for this purpose, as does the newly coined term *Map*. The second factor is the combination of a common approach in semantics—namely, using higher-order properties—with a common approach in syntax—namely, using parameters. This leads to the conceptualization of stratified reference as a *parametrized higher-order property*. Stratified reference builds on the basic intuition behind algebraic semantic accounts, namely that atelicity, distributivity and related concepts can be defined in terms of a predicate applying to the parts of an event or entity, but generalizes it by adding parameters that allow us to explicitly model varying dimensions and granularities. These parameters turn out to provide an appropriate middle ground between rigidity and flexibility that captures the ways in which distributive constructions differ without losing track of their common core. Following Piñón 2015 and Schwarzschild 2015, I have taken a further step away from ordinary higher-order properties by restricting stratified reference to the parts of a single entity x , rather than requiring it to apply to all entities to which the predicate applies. In effect, these moves made stratified reference into a relation that is higher-order on its predicate argument and on its two parameters and first-order on its entity argument. However, since its purpose is still conceptually close to higher-order properties, I will refer to it as the property-based perspective on

stratified reference:

(1) **Property-based perspective:**

$$\text{StratifiedReference}_{\text{dimension, granularity}}(\text{Predicate})(x) \stackrel{\text{def}}{=} x \in {}^*\lambda y. \left(\begin{array}{l} \text{Predicate}(y) \wedge \\ \text{granularity}(\text{dimension}(y)) \end{array} \right)$$

The *granularity parameter* allows us to model the varying amounts to which distributivity will reach down to subparts in distributive constructions: to atoms or small subgroups in some cases, and to contextually salient levels of granularity in others. This parameter is motivated in part by the need to account for the minimal-parts problem, as was done in **Chapter 5**. This problem arises from the fact that some eventualities and substances fail to distribute at very small scales because they have parts that are too small to satisfy certain mass terms and atelic predicates. This is a challenge for characterizations of atelicity that look at all smaller events (as in the case of divisive reference, Krifka 1998) or intervals (as in the case of the subinterval property, Dowty 1979). Nondivisive atelic predicates such as *waltz* and *pass on from generation to generation* make it necessary to relativize these concepts, for example by equipping them with a minimal-length threshold so that they ignore what happens at very short intervals below this threshold.

By making a virtue out of necessity and elevating this threshold to a central part of the theory—the granularity parameter—it becomes possible to avoid the minimal-parts problem. Different settings of the parameter lead to nuanced predications concerning the interaction between the respective predicate and the length of the interval denoted by the complement of *for*. By varying the parameter, we may use stratified reference both to describe the length of the smallest events that count as waltzing or passing on from generation to generation, and to describe the requirements that *for*-adverbials impose on the properties they modify. I did not fully recognize these two tasks as conceptually distinct until the response articles to Champollion 2015c, particularly Piñón 2015 and Schwarzschild 2015, helped me realize it. If a *for*-adverbial is like a sieve and the events in the denotation of the predicate it modifies are like grains of sand, the first task amounts to describing the size of the grains, and the second amounts to describing the size of the holes in the sieve (Champollion 2015b). As a part of the description of the constraint imposed by *for*-adverbials, stratified reference

describes the size of the holes. This is what Chapter 5 focuses on. As a component of meaning postulates that describe what we know about predicates, stratified reference can describe the size of the grains that pass through the sieve. Some predicates like *waltz* will be fine-grained, other predicates like *pass on from generation to generation* will be more coarse-grained.

The *dimension parameter* captures the view that unboundedness may occur in time, in space, or along a measure function or a thematic role. Because of its traditional focus on cross-domain generalizations, mereology-based algebraic semantics lends itself well to a formal implementation of this view. In particular, various functions can be treated as of one and the same kind: thematic roles such as *agent* and *theme*, measure functions such as *temperature* and *volume*, and event properties such as *runtime* and *spatial extent*. As we have seen in **Chapter 6**, the latter parallel makes it straightforward to account for analogies between temporal measure adverbials (such as *run for an hour* vs. **run all the way to the store for an hour*) and spatial measure adverbials (such as *meander for a mile* vs. **end for a mile*) previously noted by Moltmann (1991) and Gawron (2009). More generally, the dimension parameter captures the fact that a distributive construction will typically impose only one kind of unboundedness at a time. For example, the fact that temporally unbounded predicates can be modified by temporal *for*-adverbials even when they contain a spatially bounded constituent (as in *flow from the jar to the floor for ten minutes*) is unsurprising on this view, and differences in interpretation between temporal and spatial *for*-adverbials (as in *push carts all the way to the store for fifty minutes* versus *for fifty meters*) find a natural explanation.

Theories of aspect are typically not designed as ways to explain what is wrong with measure constructions like **three degrees of water* or **three pounds of book*. However, relevant connections have occasionally been noted (Krifka 1998, Schwarzschild 2006). The parallel becomes intuitive once we think of the verb phrase *run for three hours* in connection with the pseudopartitive *three hours of running*. **Chapter 7** has exploited the formal parallel between the domains of aspect and measurement developed in Chapter 4 to explain the linguistic relevance of the difference between intensive measure functions like *temperature* and extensive ones like *runtime*. Treating the two constructions as semantically equivalent made it possible to push the limits of theories designed for only one of the two domains to which they are traditionally seen as belonging. Stratified

reference correctly predicts that distributive constructions disallow measure functions that generally return the same value on an entity and on its parts. For example, just as *run for three hours* requires *run* to apply to temporally shorter parts of the event to which *run* applies, **three pounds of book* would require *book* to apply to lighter parts of the entity to which *book* applies, and **three degrees Celsius of water* would require the existence of colder parts of the entity to which *water* applies. The fact that stratified reference relativizes unboundedness to just one dimension or measure function at a time made it possible to subsume the insight of Schwarzschild 2006 and to account for examples like *five feet of snow* in spite of the fact that not every part of a five-foot snow layer of snow is less than five feet in height.

Throughout this book, I have used stratified reference for various purposes: to characterize the distributivity constraint in those constructions that impose it; to specify meaning postulates for words that exhibit distributivity down to various levels of granularity; and as a formalization of atomic and nonatomic distributivity operators. Starting in **Chapter 8**, I shifted from viewing stratified reference as a parametrized higher-order property to viewing it as a parametrized unary distributivity operator on predicates:

(2) **Operator-based perspective:**

$$\text{StratifiedReference}_{\text{dimension, granularity}}(\text{Predicate}) \stackrel{\text{def}}{=} \lambda x. x \in * \lambda y. \left(\begin{array}{l} \text{Predicate}(y) \wedge \\ \text{granularity}(\text{dimension}(y)) \end{array} \right)$$

Since the two definitions sketched in (1) and (2) are equivalent, the move from the property-based perspective to the operator-based perspective is largely conceptual. The main difference results from whether stratified reference is implemented as a presuppositional requirement or as a predicate modifier. In both cases, the dimension and granularity parameters can be instantiated in whatever ways may be appropriate for different constructions and theoretical assumptions. Varying the value of the dimension parameter amounts to distributing over various thematic roles and spatiotemporal dimensions. Varying the value of the granularity parameter amounts to choosing between distributing over atomic entities like singular individuals and nonatomic entities like pluralities and temporal intervals. Chapter 8 exploited the operator-based perspective to synthesize and expand previous accounts of how verb phrases such as *build a raft*

optionally acquire a distributive interpretation by covert distributivity operators. In particular, the differences between the atomic operator in Link 1987b, Roberts 1987, the nonatomic operator in Schwarzschild 1996, and their generalizations in Lasersohn 1998b, can be modeled and clarified by shifting the values of the dimension and granularity parameters. Furthermore, setting the dimension parameter to *runtime* made it possible to transfer the notion of covert distributivity as a verb phrase shifter into the temporal domain, and making the granularity parameter anaphoric to a salient predicate helped export Schwarzschild's claim that nonatomic distributivity requires salient covers to that domain. This resulted in a new perspective on the puzzling scopal behavior of indefinites and numerals in the scope of *for*-adverbials, including the fact that indefinites in the syntactic scope of *for*-adverbials tend not to covary with these adverbials (*?John found a flea on his dog for a month*, Zucchi & White 2001).

The operator-based perspective on stratified reference naturally led to postulating a formal connection between covert and overt distributivity. This made it possible in **Chapter 9** to analyze distance-distributive items across languages as overt versions of distributivity operators, as suggested by Link (1991b) for the case of *each*. The granularity parameter, along with the notion of an anaphoric cover from Schwarzschild 2006, made it possible to account for the crosslinguistic variation between those distance-distributive items that only exhibit atomic distributivity, such as adverbial and adnominal *each* in English, and those that also distribute over salient nonatomic entities such as time intervals, such as adverbial and adnominal *jeweils* in German. Essentially, these two items were treated as overt versions of the atomic and the nonatomic distributivity operator respectively. The typological correlation between atomic distributivity and ability to be used as a distributive determiner observed by Zimmermann (2002b) turned out to be expected once the operator-based perspective was extended to distributive determiners such as *each* and *every*. Because stratified reference always provides access to the sum event and not just to its parts, this extension immediately explained why these determiners can participate in nondistributive phenomena with items outside of their syntactic scope, such as cumulative readings and nondistributive adverbial modifiers (Schein 1993, Kratzer 2000, Champollion 2010a).

The property-based and the operator-based perspective on stratified reference, as well as both the dimension and the granularity parameter, all came into

play in **Chapter 10**, whose main focus is on explaining the behavior of *all* with respect to different collective predicates, such as *all the students gathered* versus **all the students were numerous* (Dowty 1987, Winter 2001). The impetus for this chapter came from the startling observation by Zweig (2009) that a noun phrase headed by *all*, such as *all the safari participants*, can lead to a cumulative reading when it combines with a verb phrase that contains an unbounded argument, such as the dependent plural in *saw zebras*, but not when the verb phrase contains a bounded argument, such as *saw thirty zebras*. The search for a formal property that sets these two predicates apart was facilitated by the property-based perspective. My guiding intuition was that *see zebras* is to *see thirty zebras* what *eat apples* is to *eat thirty apples*; however, the second pair captures the telic/atelic opposition while both expressions in the first pair are atelic. Stratified reference allows us to model this situation as a difference in settings of the dimension parameter. *Eat apples* but not *eat thirty apples* distributes down the time dimension; *see zebras* but not *see thirty zebras* distributes down the agent dimension. Stratified reference instantiated with *time* is atelicity; stratified reference instantiated with *agent* is distributivity. If *for*-adverbials test for atelicity, *all* tests for distributivity.

While a traditional view on distributivity might lead us to expect that *all* is synonymous with other distributive items such as *each*, the fact that different items set the granularity parameter to different values leads us to expect otherwise. The fact that *all* but not *each* is compatible with collective predicates that exhibit subgroup distributivity finds a natural explanation in the assumption that *all* is a coarser sieve than *each*, in line with the characterization of *gather*-type predicates as subgroup distributive (Dobrovie-Sorin 2014, Kuhn 2014). Stratified reference was also used to formulate meaning postulates that capture the fact that *gather*-type predicates give rise to distributive inferences to subgroups. Finally, the distributive operator from Chapter 8 helped account for cases in which *all* appears to take away the collective interpretation of a predicate that can normally be interpreted either distributively or collectively.

11.2 Future work

This section, adapted in part from Champollion 2015b,c, sketches some broader implications of strata theory and connections to other domains of linguistics.

Any theory of distributive constructions needs to specify the constraint that

these constructions impose on their constituents (the nature of the sieve) as well as the reason these constituents satisfy it (the nature of the grains that pass through the sieve). In the case of one-word predicates, I have used stratified reference to formulate meaning postulates that describe their grain size. As we have seen in Chapter 8, complex predicates can also be characterized with respect to whether or not they satisfy stratified reference. A full account of aspect and distributivity in these cases will need to be complemented by a theory of how a given complex predicate ends up having or not having stratified reference. Certain overt modifiers, such as adverbial *each* and *together*, can determine whether the predicate that they modify is understood distributively or collectively. The question of how complex predicates end up being collective or distributive is analogous to the question of how complex predicates end up being atelic or telic, a process also known as aspectual composition (e.g. Krifka 1998). Stratified reference allows us to think about the effect of *each*, *together* and distributivity operators and about aspectual composition as two sides of the same coin.

This also means that we can link problems that affect accounts of these processes. For example, Doetjes (2015) correctly notes that stratified reference does not rule out incremental-theme verbs whose themes are downward-entailing modified numerals, such as (3a). That modified numerals pose problems for algebraic accounts of aspectual composition has been noticed many times (Egg 1994, Eberle 1998, Naumann 1999). Stratified reference has this problem in common with the subinterval property, which it is meant to generalize. Cumulative reference does not fare any better because an analogous problem occurs with upward-entailing modified numerals (3b). Doetjes therefore proposes combining stratified reference with cumulative reference, following Landman & Rothstein (2012b). This will rule out both types of examples as desired, but unfortunately not (3c), discussed by Zucchi & White (2001). Likewise, the contrast in (3b), discussed by Mittwoch (1982), remains unexplained.

- (3) a. #He drank at most thirty glasses of water for three hours.
- b. #He finished at least three books for three hours.
- c. #John drank { some / a quantity of } milk for an hour.
- d. John {ate / #ate something } for an hour.

This kind of behavior is puzzling for most if not all algebraic theories of aspect, including strata theory. The noun phrases that cause the sentences in (3) to sound

odd seem to behave for the purposes of these theories as if they were quantized, at least along the relevant (temporal) dimension. An early feature-based theory of aspectual composition, Verkuyl 1972, grouped modified and unmodified numerals together by assigning both of them a [+SPECIFIED QUANTITY] feature, while bare plurals and mass nouns carried a [-SPECIFIED QUANTITY] feature. Algebraic notions like quantization, stratified reference, and the subinterval property are meant to make such features superfluous. But in noun phrases like the ones in (3), the effects of these two systems come apart (Verkuyl 2005, fn. 3). A similar issue is discussed by Schwarzschild (2015) in connection with the word *line*. Other problematic predicates include *twig*, *rock*, and *sequence*. A helpful but ultimately inconclusive discussion of possible ways to address this problem is found in Zucchi & White 2001. Similarly, as discussed in Chapter 10, a number of collective predicates that are incompatible with *all* but that are still subgroup distributive, such as *be a group of less than five*, would be expected to be compatible with *all* under the account I have discussed here (Kuhn 2014). Finally, the constraint against cumulative readings of *all* described in Chapter 10 also rules out a cumulative reading when the verb phrase contains a delimited but nonquantized object (*All the linguistics majors dated several chemistry majors*, Zweig 2009). If a solution to these problems emerges in one domain, we may well be able to adapt it to the other domain.

If this book is on the right track, distributivity is ubiquitous. We just need to recognize it when it presents itself in unusual ways. I have made the case for this idea using *each*, *all*, *for*-adverbials and pseudopartitives. Now that we know what we are looking for, it should be easy to find more distributive constructions. Here are some possible places to look:

German and Japanese split quantifier constructions, in which a quantifier appears in adverbial position apart from the noun phrase over which it quantifies, are similar to adverbial-*each* distributive constructions in that they are incompatible with collective interpretations, and they are similar to pseudopartitive constructions in that their measure functions are subject to the same monotonicity constraint (Nakanishi 2004).

As discussed in Ursini 2006, directional prepositional phrases can be modified by measure phrases when they are unbounded (*three miles towards the beach*), but not when they are bounded (**three miles to the beach*). This points towards the possibility that this is a distributive construction. The measure

phrase in these examples might be a Key, and its directional prepositional phrase a Share.

For-adverbials are not the only examples of aspectually sensitive constructions. As noted in Karttunen 1974, Hitzeman 1991, 1997, *until* is also sensitive to the atelic-telic distinction. The same appears to be true for *since*, though the situation is more complicated here. In English, *since* requires the Perfect, which is often analyzed as introducing an Extended Now interval (Dowty 1979, von Stechow 2002a). This muddles the picture, but once we move to German, where the equivalent *seit* does not require the Perfect, we see the correlation emerge:

An Extended Now Perfect modified by *since* α may embed any aktionsart. German perfects modified by *seit* α may have these readings, though they are a bit marked. In contrast to English, *seit* α may combine with simple tenses as well, but then it behaves differently. The aktionsart modified must be a state or an activity. (von Stechow 2002a)

The theory of the behavior of indefinites in the scope of *for*-adverbials presented in Chapter 8 can be extended to other modifiers that do not or not easily induce covariation of indefinites in their scope. In particular, habitual or generic sentences show analogous scopal effects to *for*-adverbials (Carlson 1977, Kratzer 2007). This is illustrated in the examples in (4), taken from Krifka, Pelletier, Carlson, ter Meulen, Chierchia & Link 1995, 39f.

- (4) a. Mary smokes cigarettes / *a cigarette.
b. Mary smokes cigarettes / a cigarette after dinner.

Just like in the case of *for*-adverbials, singular indefinites can covary with habitual operators when a salient level of granularity is provided (see also Rimell 2004).

- (5) a. Yesterday, Mary smoked cigarettes / *a cigarette for an hour.
b. Last month, Mary smoked cigarettes / a cigarette after dinner for a week.

This fact suggests that the generic quantifier might carry a stratified reference presupposition, and that it might be appropriate to fold strata theory into a more

general theory of imperfective and generic/habitual sentences such as the one proposed in Deo 2009 for English and Gujarati and extended to *for*-adverbials in Deo & Piñango 2011. Similar effects to the ones in (5) hold in Hindi (Ashwini Deo, p.c.), which is close to Gujarati. For more discussion and for a synthesis of Deo & Piñango 2011 and the present account, see Champollion 2013.

Other potential applications can be found in morphosyntax. Strata theory may help explain how boundedness is marked by semantic case in Finnish (Krifka 1992, Kiparsky 1998), by perfective prefixes in Slavic (Filip 2000), and by accusative adverbials in Korean (Wechsler & Lee 1996). Throughout this book, I have assumed that singular count nouns are interpreted as involving reference to singular entities but not sums. This was necessary in order to explain the contrast between *five pounds of books* and **five pounds of book*, and it is justified in English by the corresponding contrast in numeral phrases (*five books* vs. **five book*). Other languages, like Hungarian and Turkish, require nouns to be morphologically singular when they combine with numerals, and also when they are used as substance nouns in pseudopartitives. From the point of view of the present theory, this leads to the view that singular nouns in these languages and constructions can be interpreted as involving reference to sums. Theories that adopt this view (Farkas & de Swart 2010, Bale, Gagnon & Khanjian 2011) are compatible with the view developed here. This may be seen as an advantage for them over theories that reject this assumption (Ionin & Matushansky 2006).

I have focused on pseudopartitives like *three liters of water*. As noted by Schwarzschild (2002, 2006), true partitives like *three liters of the water* and comparatives like *more water* are subject to the same constraint on measure functions as pseudopartitives. An extension of the present account to true partitives is straightforward if we assume that the constituent *of the water* has divisive reference, stratified reference, or whatever is the relevant property of the substance nominal of pseudopartitives. However, the assumption that the *of*-PP has divisive reference is not uncontroversial: Ladusaw (1982), and many accounts that follow him, adopts it but Matthewson (2001) argues against it.

While I have shown that the behavior of a large number of constructions can be reduced to one principle (namely, sensitivity to stratified reference), I have not addressed the question why this principle exists and why these constructions are sensitive to it. In formal semantics, this is not the kind of question that is typically answered, or perhaps even answerable. There is no agreement on

whether it even needs to be answered. On the one hand, for the purposes of comparing formal semantic theories to each other, formal semantics usually pays attention to something similar to Chomskyan explanatory adequacy: “If a number of highly complex and apparently unrelated facts are reducible to a few simple principles, then these principles explain these facts” (von Stechow 1984a). On the other hand, we need not confine ourselves in this way: “we can seek a level of explanation deeper than explanatory adequacy, asking not only what the properties of language are but also why they are that way” (Chomsky 2001).

I do not know why there should be any constructions in language, let alone so many of them, that are sensitive to stratified reference or to the various properties it captures. To answer this question, it may be worth looking for explanations in domains other than formal semantics, such as first-language acquisition. Stratified reference may conceivably help first-language learners distinguish the functions of different constructions. For example, learners must distinguish constructions that specify the quantity of a substance or event, such as pseudopartitives, from superficially similar constructions that specify non-quantity-related properties, such as attributive constructions (*three-pound strawberries*). Attributive constructions do not impose stratified reference and are therefore compatible with intensive measure functions, as illustrated by *three-degree water* (Schwarzschild 2006). Apart from sometimes misinterpreting the number word in pseudopartitives as referring to cardinality of a relevant set of objects, four-year-olds tend to correctly distinguish pseudopartitives from attributives (Syrett 2013). Similarly, various studies have suggested that children are sensitive to the atelic-telic opposition as early as three years old, raising the question of how much of it is innately specified (Crain 2011). If something like the boundedness-unboundedness opposition is among the building blocks of the language faculty, then we might expect that children access it early on, and possibly that a child will learn different constructions that involve this building block at the same age.

Another kind of explanation, as well as another avenue for further research, may be found in linguistic theories that study conceptual linguistic knowledge and the mental patterns and representations in which it is organized, such as cognitive semantics (Talmy 2011) and conceptual semantics (Jackendoff 1996). The metaphor I have used to explain stratified reference, namely that individuals, substances, and events occupy regions in an abstract space whose dimensions include thematic roles and measure functions as well as spatial and temporal

dimensions, is reminiscent of the theory of conceptual spaces in Gärdenfors 2007. The words that introduce stratified reference constraints, such as *for*, *until*, *of*, *each* and *all*, belong to closed-class categories such as prepositions and determiners. Cognitive semantics has found that closed-class categories are highly constrained in the range of conceptual categories they can express. The relevant conceptual category in this case would be boundedness. While cognitive semantics is sometimes seen as opposed to formal semantics, this does not have to be so (Krifka 1998, Zwarts & Verkuyl 1994). We can make use of formal semantic techniques such as the ones I have developed here, and assume that expressions are interpreted by elements of conceptual structures rather than entities in the real world. The present system may then be seen as a step towards a model-theoretic characterization of such frameworks.