**Linking the collective-distributive opposition and the telic-atelic opposition***

Lucas Champollion

New York University

## 1. Introduction

I suggest a constraint that prevents *for*-adverbials and noun phrases headed by *each* and *all* from participating in cumulative readings with noun phrases in their syntactic scope. In all cases, the verbal predicate needs to apply to certain smaller subevents of the event it describes. I suggest that this constraint is also the reason why *for*-adverbials reject telic predicates, why *each* rejects collective predicates, and why *all* rejects certain collective predicates but not others. All these items can be seen as distributive. What distinguishes them semantically is the nature and size of the level at which they distribute: *For*-adverbials distribute down to shorter intervals; *each*, to atoms; and *all*, to subgroups.

## 2. Cumulative readings and *for*-adverbials

A cumulative reading involves two plural entities, typically expressed by a pair of definite or indefinite numerals, of which neither distributes over the other (Scha 1981):

(1) Three safari participants saw thirty zebras.

The cumulative reading of (1) can be paraphrased as "Three safari participants each saw at least one zebra, and thirty zebras were seen overall".

Zweig (2009) notes that cumulative readings can be blocked by the presence of *all* (and, less surprisingly, of *each*). Thus, the following examples cannot be paraphrased as "Each of the safari participants saw at least one zebra, and thirty zebras were seen overall".

(2) a. All the safari participants saw thirty zebras.
 b. Each of the safari participants saw thirty zebras.

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The missing reading cannot be ruled out in terms of lack of plausibility. For example, suppose that (2) is uttered in a context where there are only three safari participants. In this context, the subject noun phrases in (1) and in (2) all involve reference to the same plural individual. But while (1) has a cumulative reading, the sentences in (2) only have a subject-distributive and perhaps a doubly distributive reading. (The doubly-distributive or "branching" reading can be paraphrased as "Three safari participants each saw the same set of thirty zebras" (Barwise 1979, Sher 1997). The empirical status of this reading is controversial. Perhaps it is a limiting case of the subject-distributive reading in which the three safari participants happen to all have seen the same set of thirty zebras.)

While the prototypical examples of cumulative readings involve discrete domains such as those in which count nouns denote, the concept is easily generalized to continuous domains such as time. In the following example, adopted from Brasoveanu (2013), a plural temporal entity stands in a cumulative relation with a plural sum of individuals.

(3) This book is the product of five hundred hours of interviews with two hundred individuals.

In (1), we were able to relate each safari participant to a subset of the zebras; but in (3), we cannot relate each hour to a subset of the individuals, because some interviews may not last for an integer number of hours. Rather, the cumulative reading of (3) expresses that there is a way to divide the five hundred hours of interviews into potentially overlapping parts so that each part can be related to at least one of the individuals in question. Thus, as we generalize cumulative readings to continuous domains, we need to move from distributivity over atoms to distributivity over parts of a cover (Schwarzschild 1996). In fact, cover readings also arise in discrete domains, where they have been previously assimilated to cumulative readings (Landman 1996). The following sentence can be true even if no fire fighter individually put out any single fire:

(4) Four hundred fire fighters put out twenty fires.

Not all expressions that involve reference to time intervals are equally likely to give rise to cumulative readings:

(5) a. John saw thirty zebras.
b. John saw thirty zebras in an hour.
c. John saw thirty zebras for an hour.

Suppose John saw thirty zebras pass by him one at a time. This scenario can be felicitously described by (5a) and (5b) but not by (5c) (Krifka 1992, Eberle 1998). Now suppose John had an entire herd of thirty zebras in his field of view from noon to 1pm. Sentences (5a) and (5c) can felicitously describe this scenario, but sentence (5b) is not as natural.

The one-at-a-time scenario is analogous to situations that verify cumulative readings in the sense that each of the thirty zebras is matched to a time interval and these time intervals sum up to a three-hour timespan (perhaps with some gaps in between the zebras). The simultaneous scenario is analogous to a doubly distributive reading in the sense that each of the zebras is matched to the whole timespan. In this sense, *in*-adverbials appear to be compatible with cumulative readings, while *for*-adverbials impose stronger conditions.

These stronger conditions are already predicted by algebraic accounts of *for*-adverbials that explain their inability to modify telic predicates:

(6) a. John ate grapes for an hour. *atelic*
b. *John ate thirty grapes for an hour. *telic*

In such accounts, *for*-adverbials require the verb phrase to have some higher-order property such as the subinterval property (Dowty 1979), divisive reference (Krifka 1998), or stratified reference (Champollion 2015a,b). These requirements rule out telic verb phrases because they fail to hold at the subintervals of the time interval in question. In the one-at-a-time scenario, the verb phrase in (5c) likewise fails to apply in this way. Only in the simultaneous scenario does it hold of subevents at each subinterval of the relevant hour.

In this paper, I show that such algebraic accounts can be extended beyond *for*-adverbials to explain the absence of cumulative readings in sentences with *all* and *each* such as those in (2). I formalize this claim by using stratified reference (Champollion 2015a). In Section 3, I suggest that in contrast to *each*, which distributes all the way down to atoms, *all* distributes down to subgroups (Kuhn 2014, Dobrovie-Sorin 2014). Section 4 uses this assumption to explain the limited availability of *all* to give rise to cumulative readings, and accounts for distributive readings involving *all*. Section 5 discusses the semantic difference between *all* and *each*. Section 6 links the collective-distributive and telic-atelic oppositions and argues that the constraint that is operative in *all* and *each* is analogous to the one that leads *for*-adverbials to distinguish between telic and atelic predicates.

## 3. Distributivity and collectivity in *all* and *each*

I have previously introduced stratified reference as a way to formalize the notion of distributivity (Champollion 2010, 2015a,b). This higher-order property distributes a property $P$ over the parts of a plural entity $x$ along a dimension $d$, down to a granularity threshold $g$. In its most general formulation, stratified reference universally quantifies over all entities $x$ of the appropriate type. Let $P$ range over predicates of type $\langle \alpha, t \rangle$ where $\alpha$ is either $e$ for entities or $v$ for events, and let $x$ range over entities of type $\alpha$. Let $d$ (a "dimension") be any function from entities of type $\alpha$ to entities of type $\beta$, where $\beta$ is any type, and let $g$ (a "granularity level") be any predicate of entities of type $\beta$. Then:

(7) **Definition: Universal stratified reference**

$\mathrm{SR}_{d,g}(P) \stackrel{\mathrm{def}}{=} \forall x[P(x) \rightarrow x \in {}^{*}\lambda y[P(y) \wedge g(d(y))]]$

($P$ has universal stratified reference along dimension $d$ with granularity $g$ if and only if any $x$ in $P$ can be divided into one or more parts in $P$ that are each mapped by $d$ to something in $g$.)

For present purposes, the property $P$ will be the verbal predicate, and the parameter $g$ will encapsulate the size of the entities to which the predicate is distributed. Although it might seem natural in the context of *all* and *each* to think of the plural entities over which $x$ ranges as groups of people, I will instead let $x$ range over the plural events (or eventualities) described by the verbal predicate. Using events throughout makes it easier to draw parallels between the collective-distributive and the telic-atelic opposition. I will use the dimension parameter $d$ to mediate between the subevents of $x$ and the granularity level $g$. Specifically, $d$ will be instantiated with the thematic role of the noun phrase that hosts the determiner in question. This thematic role will map the event in question to the plural entity which is then tested for whether it is sufficiently small.

I propose that *all* requires verb phrases to apply to smaller parts of anything they apply to (cf. Kuhn 2014, Dobrovie-Sorin 2014, Champollion 2015b). Formally, I assume that *all* imposes a stratified-reference presupposition on the relevant verbal predicate. For example, if *all* heads a subject noun phrase, it presupposes that the verb phrase has stratified reference, with the parameters instantiated as described below. This essentially means that *all* makes sure that the verb phrase distributes down at least to sums that are small in number. In some cases, the verb phrase will in fact distribute down to singular individuals:

(8) All the boys smiled / arrived / won.

In other cases, the verb phrase will distribute only down to sums that are small in number, but not to singular individuals (Vendler 1962). Both cases satisfy the requirement of *all*:

(9) All the boys gathered / met / dispersed.

Because predicates like *gather*, *meet* and *disperse* do not distribute down to individuals, they are traditionally classified as collective. However, there is a generalized notion of distributivity that applies to all of them (cf. Winter 2001, p. 223f.). Namely, they distribute to subgroups that are small in number. For example, if a group of ten people gathered or dispersed, then smaller subgroups of two or three people within this group also gathered or dispersed. For this reason, the presupposition of *all* succeeds in all these sentences.

Formally, I will leave open what counts as small in number, and I will simply assume that this is determined by a placeholder predicate $\varepsilon$. This predicate takes a comparison class $K$ (either a set or a sum of entities) and an entity $x$, and returns true just in case $x$ is small (typically small in number) as compared to $K$. For example, $\varepsilon(\bigoplus \text{boy})(x)$ holds just in case $x$ is small in number compared to the sum of all boys. I assume that $\varepsilon$ is not reflexive: Nothing counts as small by comparison with itself.

After *all* combines with its thematic role and with a sum-denoting constituent such as *the boys*, it is applied to a verbal projection such as *smiled*. I write $\lambda e : \varphi \,.\, \psi$ for the partial function that is defined whenever $\varphi$ is true, and that returns $\psi$ whenever it is defined. The following entry for the determiner *all* embodies these assumptions:

(10) $[\![\text{all}]\!] = \lambda\theta\lambda y\lambda P\lambda e : \text{SR}_{\theta,\varepsilon(\theta(e))}(P).[P(e) \wedge {}^*\theta(e) = y]$

For *All the boys smiled*, this entry yields the following meaning:

(11) $\exists e : \mathrm{SR}_{\mathrm{agent},\varepsilon(\mathrm{agent}(e))}(\mathrm{smile}).[\mathrm{smile}(e) \wedge {}^*\mathrm{ag}(e) = \bigoplus \mathrm{boy}]$
(There is a smiling event $e$ whose agents sum up to the boys, presupposing that *smile* has stratified reference along the *agent* dimension with granularity $\varepsilon(\mathrm{ag}(e))$.)]

The presupposition of (11) expands as follows, where $e$ is the sum event that verifies (11):

(12) $\mathrm{SR}_{\mathrm{agent},\varepsilon(\mathrm{agent}(e))}(\mathrm{smile})$
$= \forall e'.\mathrm{smile}(e') \rightarrow e' \in {}^*\lambda e''[\mathrm{smile}(e'') \ \wedge\ \varepsilon(\mathrm{ag}(e))(\mathrm{ag}(e''))]$
(*Smile* has stratified reference along the *agent* dimension with granularity $\varepsilon(\mathrm{ag}(e))$ ("small in number compared to the agent of $e$") if and only if any smiling event can be divided into one or more smiling events whose agents are each small in number compared to the agent of $e$.)

This presupposition is satisfied because *smile* is distributive along its agent dimension (Champollion 2016a). That is, the only kinds of smiling events that have sum individuals as their agents are those that consist of several smiling events which each have an atomic agent. In general, assuming that *all the boys* refers to more than one boy to begin with, any predicate that is distributive along the relevant dimension will satisfy the presupposition in (12). To make the presentation simpler, from now on I will assume without loss of generality that *all* is always in agent position, that it modifies the definite plural *the boys*, and that the sentence is interpreted in a model where there are several boys.

Similarly, for *all the boys met*, the entry in (10) yields the following presupposition:

(13) $\mathrm{SR}_{\mathrm{agent},\varepsilon(\mathrm{agent}(e))}(\mathrm{meet})$
$= \forall e'.\mathrm{meet}(e') \rightarrow e' \in {}^*\lambda e''[\mathrm{meet}(e'') \ \wedge\ \varepsilon(\mathrm{ag}(e))(\mathrm{ag}(e''))]$
(*Meet* has stratified reference along the *agent* dimension with granularity $\varepsilon(\mathrm{ag}(e))$ if and only if any meeting event can be divided into one or more meeting events whose agents are each small in number compared to the agent of $e$.)

Because *meet* distributes down to subgroups, this presupposition is satisfied even though *meet* does not distribute down to atoms.

Any theory that treats *all* as in some sense distributive must explain how it differs from uncontroversially distributive items like *every* or *each*. I propose that while *all* only distributes down to subgroups, *every* and *each* distribute down to atomic individuals. This is why *each* is compatible with distributive predicates and incompatible with collective predicates, whether or not they distribute to subgroups:

(14) a. Each of the students smiled.
b. *Each of the students met.
c. *Each of the students was a group of ten.

Formally, I assume that *each* sets its granularity parameter to a stricter level than *all*, namely that of atoms. I develop this idea in Section 5.

We have seen in (9) that some collective predicates, which I will call *gather-type*, are compatible with *all*. However, other collective predicates are incompatible with *all* (e.g. Dowty 1987). I will call these predicates *numerous-type*:

(15) a. The students at the rally are numerous.
b. The soldiers sufficed to defeat the army.
c. The students were a group of ten.

(16) a. *All the students at the rally are numerous.
b. *All the soldiers sufficed to defeat the army.
c. *All the students were a group of ten.

I assume that the relevant semantic distinction between a predicate like *gather* and a predicate like *be a group of ten* is connected to subgroup distributivity (Kuhn 2014, Champollion 2015b). The latter kind of predicates generally do not distribute down to small subgroups, let alone to individuals. For example, a plurality of soldiers may suffice to defeat the army while small subgroups of this plurality would not suffice. Since these predicates are rejected both by *all* and by *each*, we may regard *all* in some sense as a distributive determiner.

The entry in (10) is compatible with just those collective predicates that distribute down to subgroups. That is, predicates that distribute down along the agent dimension to entities of sufficiently small size will satisfy the presupposition, while others, like *be a group of ten*, will not. Any part of an event or state that involves a group $x$ of ten people will either involve a proper part of $x$, in which case the predicate *be a group of ten* will not apply, or it will involve $x$ itself, in which case the presupposition will fail because $\varepsilon$ is not reflexive.

## 4. Why *all* can block cumulative readings

In this section, I show that the same stratified-reference presupposition that rules out certain types of collective predicates can also explain the absence of cumulative readings in sentences like (2a), repeated here:

(17) All the safari participants saw thirty zebras.

I assume that the denotation of the verb phrase *see thirty zebras* is built up compositionally by intersecting the denotation of *see* with that of *thirty zebras*. I assume that *see*, like any other verb, is closed under sum (Kratzer 2007, Champollion 2016a). This means that its denotation not only includes individual seeing events but also sums of seeing events:

(18) $[\![\text{see}]\!] = \lambda e.{}^{*}\text{see}(e)$

I assume that *theme* and other thematic roles are homomorphisms with respect to the sum operation (Krifka 1998, Champollion 2016a). For example, the theme of a sum of events is the sum of their themes. As a reminder of this assumption, I write $^*$*agent*, $^*$*theme* and so on whenever the relevant individual is or may be a plurality. I asume that the object *thirty zebras* in (17) contains a silent thematic role $^*$*theme* and that it too is interpreted as a predicate of (potentially sum) events:

(19) $[\![\text{[theme] thirty zebras}]\!] = \lambda e.|^*\text{th}(e)| = 30 \wedge {}^*\text{zebra}(^*\text{th}(e))$

Combining (18) and (19) by intersection yields the set of all seeing events whose themes sum up to thirty zebras:

(20) $[\![\text{see thirty zebras}]\!] = \lambda e.^*\text{see}(e) \wedge |^*\text{th}(e)| = 30 \wedge {}^*\text{zebra}(^*\text{th}(e))$
(True of any potentially plural seeing event whose themes sum up to thirty zebras.)

Since *see* is closed under sum, among the events to which (20) applies there will be some which are composed of more than one seeing event. Thus if Tom, Dick, and Harry each saw a different sum of ten zebras, the sum of these three events is also a seeing event (call it $e_0$), and its theme is a sum of thirty zebras. Therefore the predicate (20) holds of $e_0$.

Suppose now that *the safari participants* and therefore *all the safari participants* refers to the sum of Tom, Dick, and Harry. We can now explain why sentence (17) does not have a cumulative reading. The lexical entry for *all* in (10) imposes the following stratified-reference presupposition on the verb phrase *see thirty zebras*, whose meaning is as in (20):

(21) $\text{SR}_{\text{agent},\varepsilon(\text{agent}(e))}([\![\text{see thirty zebras}]\!])$
$= \forall e'.[\![\text{see thirty zebras}]\!](e') \rightarrow$
$e' \in {}^*\lambda e''[[\![\text{see thirty zebras}]\!](e'') \wedge \varepsilon(^*\text{ag}(e))(^*\text{ag}(e''))]$
(True if and only if any potentially plural seeing event involving thirty zebras can be divided into (sums of) seeing events whose agents are each small in number compared to the agent of *e*, and which each have thirty zebras as their theme.)

The event $e_0$ falsifies this presupposition for the following reason. It is a plural seeing event whose themes sum up to thirty zebras. While it can be divided into seeing events with fewer agents than $e_0$, none of these events involves thirty zebras. For example, the largest seeing event whose agent is the sum of Tom and Dick only involves twenty zebras.

One may think at first sight that this account wrongly predicts (17) to be felicitous in a scenario in which there are many safari participants and thirty zebras, and subgroups of two or three safari participants between them saw these thirty zebras but no individuals did. However, the existence of the event $e_0$ suffices to make (21) fail even though this event is unrelated to anything that transpires in the scenario at hand. This is because universal stratified reference quantifies over all seeing-thirty-zebras events whatsoever (and therefore also over any events in the model that are like $e_0$) rather than only those that are part of the scenario. (In Champollion (2015a), I analyzed both *all* and *for*-adverbials in terms of restricted stratified reference, a weaker notion which does not rule out predicates that fail to apply to events outside of the present scenario. This would lead to overgeneration in a scenario where the safari participants can be divided into groups of two or three such that each group saw a different set of thirty zebras. No corresponding overgeneration seems to affect the analysis of *for*-adverbials. Therefore, in Section 6 below, I analyze them via restricted stratified reference.)

This account leads us to expect that *all* should not prevent cumulative readings across the board. For example, it should block them in connection with verb phrases like *see thirty zebras*, but not with verb phrases like *see zebras*:

(22) All the safari participants saw zebras.

The plural *zebras* in (22) is dependent on *all* and can indeed be analyzed essentially along the same lines as a cumulative reading (Zweig 2009).

Specifically, I assume that the literal meaning of *zebras* is *one or more zebras*, and that its full interpretation as *two or more zebras* is due to an implicature (cf. Spector 2007). This means that the verb phrase of (22) is literally interpreted as follows:

(23) $[\![\text{see zebras}]\!] = \lambda e.{}^*\text{see}(e) \wedge {}^*\text{zebra}({}^*\text{th}(e))$
(True of any potentially plural seeing event whose themes sum up to one or more zebras.)

Unlike *see thirty zebras*, this verb phrase satisfies the stratified-reference presupposition on the plausible assumption that any sum of seeing events whose themes are zebras consists of seeing events whose agents are atomic individuals and whose themes are zebras:

(24) $\text{SR}_{\text{agent},\varepsilon(\text{agent}(e))}([\![\text{see zebras}]\!])$
$= \forall e'.{}^*\text{see}(e') \wedge {}^*\text{zebra}({}^*\text{th}(e')) \rightarrow$
$e' \in {}^*\lambda e''[{}^*\text{see}(e'') \wedge {}^*\text{zebra}({}^*\text{th}(e'')) \ \wedge \ \varepsilon({}^*\text{ag}(e))({}^*\text{ag}(e''))]$
(True if and only if any seeing event, or sum of seeing events, whose theme is a sum of zebras can be divided into (sums of) seeing events $e''$ such that the agent of any $e''$ is small in number compared to the agent of $e$, and the theme of $e''$ is one or more zebras.)

We have now explained why the verb phrase *see thirty zebras* lacks a cumulative reading in a sentence like (22). But what accounts for its distributive reading? I assume that it is generated by applying a covert distributivity operator to the verb phrase before it combines with the subject (Link 1991). I will adopt the following operator, which is coindexed with the thematic role of the plural entity over which it distributes (Champollion 2016a):

(25) **Definition: Event-based D operator**
$[\![\text{D}_\theta]\!] = \lambda V \lambda e[e \in {}^*\lambda e'(V(e') \wedge \text{Atom}(\theta(e')))]$

When this operator is coindexed with *agent* and applied to the verb phrase *see thirty zebras* as defined in (20), it yields the following result:

(26) $[\![\mathrm{D}_{ag}$ [see thirty zebras]$]\!]$
$= \lambda e[e \in {}^*\lambda e'({}^*\mathrm{see}(e') \wedge |{}^*\mathrm{th}(e')| = 30 \wedge {}^*\mathrm{zebra}({}^*\mathrm{th}(e')) \wedge \mathrm{Atom}(\mathrm{ag}(e')))]$ (True of any sum of potentially plural seeing events each of which has an atomic agent and a sum of thirty zebras as its theme.)

Unlike (20), this verb phrase satisfies the stratified-reference presupposition of *all*. More generally, one can show that the output of the distributivity operator in (25) always has stratified reference along the dimension specified by the role $\theta$ with which (25) is coindexed (Champollion 2010). The intuition is the following. Suppose Tom, Dick, and Harry each saw thirty zebras. Then each of these three events is in the denotation of the nondistributive verb phrase (20). Since each of them has an atomic agent and since $P \subseteq {}^*P$ for any $P$, each of these events is also in the denotation of the distributive verb phrase (26). Moreover, any sum of such events is also in the denotation of (26). In general, all events in the denotation of (26) will consist of such events, hence (26) has stratified reference.

This means that in a sentence with *all*, the distributivity operator can be seen as a repair strategy. When it applies to a verb phrase that would otherwise fail the presupposition of *all*, the result satisfies it. This prediction is borne out in certain lexically mixed predicates, particularly states and achievements (Taub 1989):

(27) a. The stones are heavy. / The boys won. *distributive/collective*
b. All the stones are heavy. / All the boys won. *only distributive*

Potential counterexamples arise in certain sentences involving accomplishment and activity predicates (Taub 1989). These sentences sometimes tolerate collective readings with *all* even if they do not license subgroup distributivity:

(28) All the boys built a raft / carried a piano around. *distributive/collective*

A possible explanation is due to Brisson (2003), who assumes that the scope of the D operator can be optionally restricted to a silent event predicate 'DO' that is licensed in sentences with such predicates. This effectually neutralizes the distributing effect of *all*:

(29) All the boys [ $\mathrm{D}_{ag}$ DO ] [built a raft]. *collective*

In principle, this assumption would be compatible with the present theory, particularly if we assume that *all the boys* only takes scope over [ $\mathrm{D}_{ag}$ DO ] to the exclusion of the rest of the verb phrase. However, I adopting this approach would permit cumulative readings in sentences involving *all* and activity predicates. But example (30), with an activity predicate, lacks a cumulative reading. How to explain this while accounting for the collective reading in (28) remains an open question both for Brisson (2003) and for the present account.

(30) All the linguistics majors dated several chemistry majors. (Zweig 2009)

## 5. From *all* to *each*: Different granularity levels

As we have seen, certain collective predicates, such as *be numerous* and *be a group of ten*, are incompatible with both *each* and *all*, while others such as *gather* and *disperse* are incompatible with *each* but compatible with *all*. I have suggested that this is because *all* requires the verbal predicate to apply to subevents whose agents are small in number. This means that we can think of *all* as a sieve. In order for a predicate to pass through this sieve, it must distribute down to sufficiently small parts. In fact, *all* is like a coarse sieve, in the sense that the parts are allowed to have nonatomic agents. I suggest that we can think of *each* as a fine sieve. Like *all*, it imposes distributivity, but unlike *all*, it imposes distributivity down to atomic individuals. A predicate like *smile* will pass through both sieves because it distributes down to atomic agents, while a predicate like *gather* passes only through the coarse sieve because it distributes only down to subgroups.

More formally, to explain why *gather* distinguishes between *each* and *all*, I assume following Kuhn (2014) that *each* distributes over events with atomic individuals while *all* distributes over events whose agents must be small in number but need not be atomic. The following entry from Champollion (2016b) implements this assumption:

(31) $[\![\text{each}]\!]_{\text{determiner}}$
$= \lambda P \lambda \theta \lambda V \lambda e\, [\theta(e) = \bigoplus P \wedge [\![D_\theta]\!](V)(e)]$
$= \lambda P \lambda \theta \lambda V \lambda e\, [\theta(e) = \bigoplus P \wedge e \in {}^*\lambda e'[V(e') \wedge \text{Atom}(\theta(e'))]]$

On this view, determiner *each* divides the relevant event into parts which satisfy the verb phrase and whose agents are atoms. For a sentence like *each boy smiled*, this entry yields the following meaning:

(32) $[\![\text{Each boy smiled}]\!]$
$= \exists e[{}^*\text{agent}(e) = \bigoplus \text{boy} \wedge e \in {}^*\lambda e'[{}^*\text{smile}(e') \wedge \text{Atom}(\text{agent}(e'))]]$

This says that there is an event $e$ whose agent is all the boys and which consists entirely of smiling events whose agents are atoms. Since *agent* is a sum homomorphism, we know that these atoms must sum up to $\bigoplus$boy. On the assumption that every boy is modeled as an atom, this entails that the agents of the smiling events are boys.

Since any distributive predicate has stratified reference along the *agent* dimension with granularity *Atom*, it will be compatible with *each*. Collective predicates do not have this property, and will therefore generally lead to category mistakes. For example, the following sentence would require the existence of gathering events whose agents are individual boys.

(33) $[\![\text{*Each boy gathered}]\!]$
$= \exists e[{}^*\text{agent}(e) = \bigoplus \text{boy} \wedge e \in {}^*\lambda e'[{}^*\text{gather}(e') \wedge \text{Atom}(\text{agent}(e'))]]$

At this point, the question might arise whether *all* could be treated analogously to *each* in (31), just with the *Atom* parameter replaced by $\varepsilon(\text{agent}(e))$:

(34) $\lambda P \lambda \theta \lambda V \lambda e\, [\theta(e) = \bigoplus P \wedge e \in {}^*\lambda e'[V(e') \wedge \varepsilon(\text{agent}(e))(\theta(e'))]]$

Instead of presupposing that the verbal predicate distributes down to events whose $\theta$s are small in number, this entry would simply distribute the predicate down to these events itself. I do not follow this strategy because it would lead to an overgeneration problem in connection with cumulative readings. Sentence (17) (*All the safari participants saw thirty zebras*) would be wrongly predicted to be true in a scenario where the safari participants can be divided into small groups that each saw a different sum of thirty zebras.

## 6. Distributivity and atelicity

We are now ready to link the collective-distributive opposition to the telic-atelic opposition, which is commonly associated with *for*-adverbials. I suggest that the constraint that is operative in *all* and *each* is analogous to the one that leads *for*-adverbials to reject telic predicates. I will formalize this claim by capturing distributivity as well as atelicity via stratified reference (Champollion 2015a,b). The general point, however, is independent of the formalism chosen.

As mentioned, theories of *for*-adverbials typically check whether the verbal predicate has some higher-order property. Many of these properties, including not only stratified reference but also divisive reference and the subinterval property, amount to checking whether the verbal predicate applies to certain subevents or subintervals of the event or interval in question. The subinterval property holds of a predicate $P$ iff $P$ holds at each moment of any interval at which it holds. Divisive reference holds of $P$ iff $P$ applies to each part of any event to which it applies. The occurrence of the word *each* in these definitions makes it clear that they are intimately related to distributivity.

The granularity parameter plays a key role, as it has done throughout this paper. Just like the word *all* stops short of distributing the predicate down to singular individuals, the *for*-adverbial stops short of requiring the predicate to hold at infinitely short subintervals. This avoids the minimal-parts problem (Dowty 1979). In fact, it may be that all we need to say about *for*-adverbials is that they distribute to proper subintervals, as opposed to very short proper subintervals (Piñón 2015, Schwarzschild 2015). In the spirit of the gradable notion of distributivity that stratified reference provides, we might say that *for*-adverbials are only slightly distributive. That is, it may be that *for*-adverbials instantiate their granularity parameter not with $\lambda i.\varepsilon(\tau(e))(i)$ but with $\lambda i.i < \tau(e)$, where $\tau$ is the temporal trace function and $<$ is the proper-part relation over intervals. I will base my treatment of *for*-adverbials on the one in Champollion (2015a). In that paper, I introduce a version of stratified reference that is restricted to a given entity or event, rather than quantifying over all entities in the denotation of the predicate:

(35) **Restricted stratified reference**
$\text{SR}_{f,g} \stackrel{\text{def}}{=} \lambda P \lambda x [x \in {}^*\lambda y\, (P(y) \wedge g(f(y)))]$
($x$ can be divided into one or more $P$-parts, each mapped by $f$ to something $g$.)

The following translation uses this restricted version of stratified reference. It takes an event predicate *P* (typically a verb phrase denotation) and an event *e* which is presupposed to consist of *P*-subevents whose runtimes are shorter than that of *e*. Provided this presupposition is satisfied, the event is mapped to True just in case it is itself a *P*-event and its runtime measures an hour:

(36) $[\![\text{for an hour}]\!] = \lambda P_{\langle v,t \rangle} \lambda e : \text{SR}_{\tau, \lambda i. i < \tau(e)}(P)(e).\, P(e) \wedge \text{hours}(\tau(e)) = 1$

This translation rules out telic predicates in the usual way (cf. Krifka 1998). For example, a sentence like *John ate grapes for an hour* will be true if there is an eating event $e_0$ whose theme is a sum of (literally) one or more grapes and whose runtime is an hour-long interval $h_0$, provided that the presupposition is satisfied. The sentence presupposes that *e* can be divided into eating events whose themes are sums of one or more grapes and whose runtimes are proper subintervals of $h_0$. This will generally be easy to satisfy, especially if the grapes are eaten one or two at a time. As for the presupposition of a sentence like **John ate thirty grapes for an hour*, it will fail because there will be no way to divide the event in the required way (the subevents will involve sums of less than thirty grapes).

Some of the reasons for using the restricted rather than the universal version of stratified reference for *for*-adverbials are laid out in Piñón (2015), Schwarzschild (2015), and Champollion (2015a). Another reason is the difference in interpretation between (5b) and (5c), repeated here as (37a) and (37b):

(37) a. John saw thirty zebras in an hour. $\rightsquigarrow$ *one at a time*
b. John saw thirty zebras for an hour. $\rightsquigarrow$ *simultaneously*

Accounting for this difference without ruling (37b) out altogether would be difficult if we used universal stratified reference, because not every see-thirty-zebras event can be divided into seeing-thirty-zebras subevents (the one-at-a-time scenario is a counterexample). By contrast, the difference can be explained straightforwardly if we use the restricted version of stratified reference because it is relativized to the sum event in question. That is, (37b) presupposes that this sum event can be divided into parts that each qualify as *see thirty zebras*:

(38) **Presupposition of (37b):**
$e \in {}^*\lambda e' \, ({}^*\text{see}(e') \wedge {}^*\text{zebra}(e') \wedge |{}^*\text{th}(e')| = 30 \wedge \tau(e') < \tau(e))$
(The event *e* in question can be divided into seeing events whose themes each sum up to thirty zebras and whose runtimes are shorter than that of *e* itself.)

This presupposition is satisfied in the simultaneous scenario but not in the one-at-a-time scenario. As for (37a), it is satisfied in the one-at-a-time scenario because it has no such presupposition. For an account of why it cannot be used felicitously in the simultaneous scenario, see Krifka (1998).

## 7. Conclusion

I have argued that the constraint that prevents *for*-adverbials from modifying telic predicates is also operative in *all* and *each*. I have used this parallel to explain why both *for* and *all* reject cumulative readings. To formalize this idea, I used stratified reference, which allows us to model distributivity as a gradable notion.

We might call *each* a "completely distributive" determiner, in the sense that it distributes all the way down to atoms. In this sense it contrasts with *all*, which is only an "almost distributive" determiner (it only requires subgroup distributivity). *Gather*-type predicates are "a bit distributive" in the sense that they have subgroup distributivity, while *numerous*-type predicates are not even that. Stratified reference captures this gradable notion of distributivity because of its granularity parameter.

Lucas Champollion
champollion@nyu.edu

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