Varieties of Distributivity: *One by One* vs *Each*

Adrian Brasoveanu, Robert Henderson – UC Santa Cruz
abrsvn,rmh@ucsc.edu

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1 Introduction

Example (1) is compatible with events that unfold in very different ways. The addition of *one by one* in (2) constrains how the leaving events can proceed.

(1) The boys left.

(2) The boys left one by one.

Intuitively, *one by one* is an event modifier that targets a plural participant in the event.

- it breaks an event down into temporally sequenced subevents
- it distributes the plural participant over these subevents

(3)
$$\begin{array}{rcccccc} \mathbf{e} & = & \mathbf{e}_1 & \oplus & \mathbf{e}_2 & \oplus & \dots \\ & & \textsc{leave}(\mathbf{e}_1) & & \textsc{leave}(\mathbf{e}_2) & & \dots \\ & & \mathbf{runtime}(\mathbf{e}_1) & \prec & \mathbf{runtime}(\mathbf{e}_2) & \prec & \dots \\ \mathit{the.boys} & = & \mathit{boy}_1 & \oplus & \mathit{boy}_2 & \oplus & \dots \\ & & \mathbf{ag}(\mathbf{e}_1) = \mathit{boy}_1 & & \mathbf{ag}(\mathbf{e}_2) = \mathit{boy}_2 & & \dots \end{array}$$

Goals:

- **immediate goal (on which we focus today):** investigate the constraints on the distribution and interpretation of *one by one* and give a compositional semantics for *one by one* that captures them
- **larger goal:** motivate two routes to establishing distributive quantificational dependencies – exemplified by *each* and *one by one*, respectively
  - **decomposition into sets of assignments:** each n-tuple of quantificationally dependent entities is individually stored in a variable assignment and quantifiers are interpreted relative to the entire set of variable assignments (van den Berg 1996 and Nouwen 2003 among others)

(4) The boys each recited a poem.

(5)

G	x (boys)	y (poems)	
g_1	boy_1 $(= g_1(x))$	poem_1 $(= g_1(y))$	boy_1 recited poem_1
g_2	boy_2 $(= g_2(x))$	poem_2 $(= g_2(y))$	boy_2 recited poem_2
$\dots$	$\dots$	$\dots$	$\dots$

  - ∗ *each* breaks the plural individual *the.boys* into atoms and stores each boy in a variable assignment: boy_1 in g_1, boy_2 in g_2 etc.
  - ∗ the remainder of the sentence is interpreted relative to each variable assignment, so we store a (possibly different) poem in each assignment, relative to each boy
  - **encapsulation into a function:** functions, e.g., Skolem functions, store quantificational dependencies as a whole, mapping each entity to the (possibly non-atomic) entity that depends on it (Stone 1999, Bittner & Trondhjem 2008 and Dekker 2008 among others)

(6) The boys recited a poem one by one.

(7)

	x (boys)	f (boy-poem dependency)
g	*the.boys*	$f = \begin{bmatrix} \mathit{boy}_1 & \mapsto & \mathit{poem}_1 \\ \mathit{boy}_2 & \mapsto & \mathit{poem}_2 \\ & \dots & \end{bmatrix}$

Both encapsulation and decomposition allow cross-sentential anaphora (see Stone 1999 and Bittner & Trondhjem 2008 for encapsulation-based accounts of such anaphora).

(8) a. One by one, the boys chose a book.
b. Then, one by one, they opened it and read out the title.

(9) a. The boys each chose a book.
b. Then, they each opened it and read out the title.

The two routes to distributivity enable us to capture the fact that *each*, but not *one by one*, licenses internal readings of *different*:

(10) The boys each recited a different poem.

- for any two boys a and b, the poem a recited is different from the poem b recited
- in (5), we get this by comparing variable assignments in a pairwise way (see Brasoveanu 2008 for more details)

(11) The boys recited a different poem one by one.

- the internal reading is not available because there is only one variable assignment in (7)

Core proposal: *one by one* is an event modifier that encapsulates part of a θ-role function.

- θ-role functions map events to their participants
- *one by one* targets a θ-role function and structures it so that linearly ordered atomic subparts of the event are mapped onto atomic subparts of a plural participant
- so, *one by one* does not directly introduce the boy-poem function f in (7) above – such a function is induced via events and θ-role functions

Roadmap:

- the distribution and interpretation of *one by one*
- outline of the account: *one by one* and θ-roles
- conclusion

2 The Distribution of *One by One*

Most of the examples in this section are from the Corpus of Contemporary American English (`http://www.americancorpus.org/`).

- large, balanced corpus of contemporary American English – 385 million words of text, including 20 million words each year from 1990-2008, equally divided among spoken (78.8 million words), fiction (74.9 million words), popular magazines (80.7 million words), newspapers (76.3 million words) and academic texts (76.2 million words)
- *one by one* tokens: 2774; frequency: $\sim$ 7 / mil (spoken: 4 / mil, fiction 19.7 / mil, magazines: 6.1 / mil, newspapers 4.3 / mil, academic 2.1 / mil)

Main generalizations:

- *one by one* needs to target a nominal argument / adjunct
- the nominal argument / adjunct has to be local – basically, in the same clause as the verbal predicate that *one by one* modifies

2.1 Types of Nominal Targets

- subjects

(12) One by one, 63 North Koreans stepped through the heavily fortified border zone.

(13) The sucker holes closed, one by one.

- direct objects

(14) One by one, he eliminates the contestants.

(15) I brought him my singers one by one.

- prepositional phrases

(16) Joe came back for the boxes, one by one.

(17) He waved forked fluorescent scanners over the vials one by one to catch anything in the solutions that didn't register chemically.

(18) He was followed, one by one, by his companions.

However, there seem to be some restrictions on the kind of nominals that *one by one* can target.

(19) I loaded pumpkins onto the truck one by one.

(20) *I loaded the truck with pumpkins one by one.

(21) I sprayed the walls with (a can of) paint one by one.

(22) *I sprayed (a can of) paint onto the walls one by one.

One by one targets a variety of arguments / adjuncts – but crucially, it must have a target. Out of 1000 occurrences in COCA that we examined closely, there is only one more or less felicitous example without a nominal target.

(23) [Inside an old factory building in Cambridge, Mass., a remarkable machine with the improbable name Zeus is hard at work. Flexing its two robotic arms, the computer-driven device reaches again and again into a storage area the size of a toddler's crib, where thousands of individual samples of genetic material sit in tiny wells etched into plastic plates, each one identified by a unique bar code.]
One by one, Zeus searches for a particular code, dips into the corresponding well with a fine, quill-like probe and picks up a minuscule droplet of liquid DNA.

(24) [Compare with:] Well by well, Zeus searches for a particular code.

The plural-nominal-target constraint distinguishes *one by one* from other similar event modifiers, e.g., *brick by brick*, *simultaneously* or *consecutively*.

(25) I tore the house down brick by brick.

(26) *I tore the house down one by one.
(plurality required)

(27) The city ordered the demolition to be done brick by brick.

(28) *The city ordered the demolition to be done one by one.
(nominal target required)

(29) It got dark and it started to rain simultaneously.

(30) Consecutively, it got dark and it started to rain.

(31) *It got dark and it started to rain one by one.
(nominal target required)

2.2 Locality of the Nominal Target

One by one does not require strict adjacency, but the nominal target has to be in the same clause as the event-contributing predicate that *one by one* modifies.

- the felicity of the sentences below depends on the position of *one by one*
- we obtain different readings depending on the position of *one by one*

(32) But when, one by one, their units were activated, Mr. Lozano slowly realized that if war in the Persian Gulf came his family could be wiped out.
(activate one by one)

(33) *But one by one, when their units were activated, Mr. Lozano slowly realized that if war in the Persian Gulf came his family could be wiped out.

(34) *But when their units were activated, Mr. Lozano slowly realized that if war in the Persian Gulf came one by one, his family could be wiped out.

(35) But when their units were activated, Mr. Lozano slowly realized that if war in the Persian Gulf came, his family could be wiped out one by one.
(wipe out one by one)

One by one can operate across multiple, conjoined predicates only when it syntactically scopes over them.

(36) Over those busy decades, as one by one our nestlings fledged and took wing ...
(✓fledge one by one)

(37) Over those busy decades, as our nestlings fledged and one by one took wing ...
(*fledge one by one)

(38) It was sad that one by one our nestlings fledged and took wing. (✓take wing one by one)

(39) It was sad that one by one our nestlings fledged and that they took wing. (*take wing one by one)

Locality can be specified in syntactic terms (clause-boundedness) or in semantic terms.
For example, we could say that *one by one* needs to target a participant in the event it modifies. But this event can have a complex internal structure – e.g., *make regret* in (40) below – and *one by one* can target a participant in an embedded subevent.

(40) One by one, I'm going to make Harvey regret all those lies he told.[1]

If causative structures like *make regret* are syntactically biclausal, then characterizing the locality of *one by one* in semantic terms is more adequate. For simplicity, we will continue to characterize it in syntactic terms.

2.3 The Internal Structure of the Nominal Target

The plurality of the nominal target does not need to be morphologically realized. *One by one* is compatible with:

[1] We are indebted to Jorge Hankamer for this example.

- group-denoting nouns

(41) One by one that baffled, costumed crew slunk away into the shadows.

(42) She said good-bye to her staff one by one.

- conjoined NPs

(43) Jan dredged from a Safeway bag, one by one, a can of baby corn cobs, a tin of Norwegian sardines, and a glass jar crammed with tiny white cocktail onions.

(44) In the next hour, a manager, a lawyer and three publicists will, one by one, approach Ms. Paltrow's table.

- quantifiers headed by *every / each*

(45) One by one, every student present began to applaud.

(46) The provost called each man in the company one by one to be interviewed.

(47) One by one, we each set our Ortovox transceivers on transmit while the others listen.

(48) One by one each tells his story of life around the King of Kings.

- pseudo-partitives

(49) A squad of unknown terrorists walked one by one into several subway stations during the peak of rush hour Friday afternoon.

(50) One by one, he dropped on the table a series of snapshots he had taken.

- partitives, including *most / each*-based partitives

(51) Linguini watches – stunned – as, one by one, the rest of the staff exits.

(52) Most of those killed were unarmed prisoners, boys and men, shot in groups, or sometimes one by one.

(53) Then, one by one, at several-minute intervals, each of us sets out on a solitary walk.

Summary of the generalizations:
• *one by one* targets a nominal argument / adjunct
• the nominal argument / adjunct has to be local – in the same clause as the verbal predicate that *one by one* modifies
• the nominal target needs to be semantically, but not morphologically, plural

3 Outline of the Account: *One by One* and θ-role Encapsulation

- syntactically: *one by one* is a verbal adjunct (Jackendoff 2008)
- semantically: *one by one* is an event modifier that targets a plural participant in the event it modifies
- not immediately obvious how to compositionally capture the fact that *one by one* simultaneously targets an event and an individual

Proposal: *one by one* targets the cumulative closure of a θ-role function.

- we capture the nominal target constraint: θ-roles are not assigned when there is no overt argument
- we capture locality: θ-roles are clause-bounded
- the cumulative closure enables us to account for nominal targets that are morphologically singular, but semantically plural, e.g., DPs headed by *every / each*

Cumulative closure:

  - properties: for any set P, $^*P$ is the smallest set such that $P \subseteq {}^*P$ and, if $a \in {}^*P$ and $b \in {}^*P$, then $a \oplus b \in {}^*P$ (Link 1983)
  - relations (or functions): for any n-place relation R, $^{**}R$ is the smallest relation such that $R \subseteq {}^{**}R$ and, if $\langle a_1, \ldots, a_n \rangle \in {}^{**}R$ and $\langle b_1, \ldots, b_n \rangle \in {}^{**}R$, then $\langle a_1 \oplus b_1, \ldots, a_n \oplus b_n \rangle \in {}^{**}R$ (based on Krifka 1986)

Thus, the distributive quantificational dependencies introduced by *one by one* are the dependencies encapsulated in the targeted θ-role function.

3.1 A Closer Look at the Formalization

We work with classical (many-sorted) type logic:

- the domain of individuals of type e is the powerset of a designated set of entities IN minus the empty set: $D_e = \wp^+(\mathsf{IN}) = \wp(\mathsf{IN}) \setminus \emptyset$
- the domain of events of type ϵ is the powerset of a designated set of events EV minus the empty set: $D_\epsilon = \wp^+(\mathsf{EV}) = \wp(\mathsf{EV}) \setminus \emptyset$

- atomic individuals and atomic events are the singleton sets in $\wp^+(\mathsf{IN})$ and $\wp^+(\mathsf{EV})$ respectively; they are identified by a predicate **atom** (which applies to both individuals and events)
- the "part of" relation $\leq$ over individuals / events is set inclusion over $\wp^+(\mathsf{IN})$ / $\wp^+(\mathsf{EV})$: $a \leq b$ iff $a \subseteq b$
- the sum operation $\oplus$ is set union over $\wp^+(\mathsf{IN})$ / $\wp^+(\mathsf{EV})$: $a \oplus b := a \cup b$
- θ-roles are functions of type ϵe from events (type ϵ) to individuals (type e)
- for example, **th** is the theme role, **ag** is the agent role etc.
- cumulative closure for θ-role functions: $^{**}\mathbf{ag}$ is the smallest set of $\langle \text{event}, \text{individual}\rangle$-pairs such that $\mathbf{ag} \subseteq {}^{**}\mathbf{ag}$ and, if $\mathbf{ag}(\mathbf{e}) = x$ and $\mathbf{ag}(\mathbf{e}') = x'$, then $^{**}\mathbf{ag}(\mathbf{e} \oplus \mathbf{e}') = x \oplus x'$

Arguments and adjuncts are event modifiers:

- they have denotations of type $(\epsilon t)(\epsilon t)$
- they have translations of the form $\lambda\mathcal{P}_{\epsilon t}.\lambda\mathbf{e}_\epsilon.\ \mathcal{P}(\mathbf{e}) \wedge \ldots$

Arguments and adjuncts are syntactically indexed with their θ-roles and this indexation percolates up the tree: as we go higher in the functional layer built on top the main lexical verb, we accumulate more and more θ-role indices. These θ-role indices are not visible beyond the top functional projection of the lexical verb (hence *one by one* modification is clause-bounded).

(54) $[^{\mathbf{ag},\mathbf{th}}_{IP}\ [_{DP}\ \text{The}^{\mathbf{ag}}\ \text{boys}\ ]\ [^{\mathbf{th}}_{I'}\ \text{recited}\ [_{DP}\ \text{`The Raven'}^{\mathbf{th}}\ ]\ ]\ ]$

Syntax/semantics constraint: *one by one* can target any of the θ-roles that its syntactic sister is indexed with – but only them.

(55) $\text{one by one}_\theta\quad [^{\theta_1,\theta_2,\cdots}_{XP}\ \ldots],\quad$ where $\theta \in \{\theta_1, \theta_2, \ldots\}$

- since *one by one* needs to target a θ-role, this constraint effectively requires its sister node to be indexed with at least one θ-role

The meaning of *one by one* (subscripts on terms indicate their types):

(56) $\begin{array}{l} \textit{one by one}_\theta \rightsquigarrow \lambda\mathcal{P}_{\epsilon t}.\lambda\mathbf{e}_\epsilon.\ \mathcal{P}(\mathbf{e}) \wedge \\ \mathbf{linear.order}(\{\mathbf{e}' \leq \mathbf{e} : \mathbf{atom}(\mathbf{e}')\}) \wedge \\ |\,\{x_e \leq {}^{**}\theta(\mathbf{e}) : \mathbf{atom}(x)\}\,| > 1 \wedge \\ \forall\mathbf{e}' \leq \mathbf{e}(\mathbf{atom}(\mathbf{e}') \rightarrow |\,\{x_e \leq {}^{**}\theta(\mathbf{e}') : \mathbf{atom}(x)\}\,| = 1) \end{array}$

- $|X|$ is the cardinality of X

The last three conjuncts in (56) give the contribution of *one by one*:

- $\mathbf{linear.order}(\{\mathbf{e}' \leq \mathbf{e} : \mathbf{atom}(\mathbf{e}')\})$ requires the atomic subevents of the event $\mathbf{e}$ under discussion to be temporally sequenced
- $|\,\{x_e \leq {}^{**}\theta(\mathbf{e}) : \mathbf{atom}(x)\}\,| > 1$ ensures that *one by one* targets only plural participants in the event
- $\forall\mathbf{e}' \leq \mathbf{e}(\mathbf{atom}(\mathbf{e}') \rightarrow |\,\{x_e \leq {}^{**}\theta(\mathbf{e}') : \mathbf{atom}(x)\}\,| = 1)$ ensures that there is a one-to-one, θ-based correspondence between each atomic subevent of the event $\mathbf{e}$ and each atomic individual in $^{**}\theta(\mathbf{e})$

So, *one by one* contributes part of the dependency encapsulated in the function θ: that part that relates the atoms of the plural event $\mathbf{e}$ and their (atomic) participants.
Two by two has the same translation as *one by one* except that the last subformula is $|\,\{x_e \leq {}^{**}\theta(\mathbf{e}') : \mathbf{atom}(x)\}\,| = 2$.

3.2 Some Examples

In (57), *one by one* can only be indexed with the **ag** role because the theme is singular.

(57) $\text{The}^{\mathbf{ag}}$ boys recited 'The Raven'$^{\mathbf{th}}$ $\text{one by one}_{\mathbf{ag}}$.

(58) $\textit{recite} \rightsquigarrow \lambda\mathbf{e}_\epsilon.\ \textsc{recite}(\mathbf{e})$

(59) $\begin{array}{l} \textit{`The Raven'}^{\mathbf{th}} \rightsquigarrow \lambda\mathcal{P}_{\epsilon t}.\lambda\mathbf{e}_\epsilon. \\ \mathcal{P}(\mathbf{e}) \wedge \mathbf{th}(\mathbf{e}) = \textsc{the-raven} \end{array}$

(60) $\textit{the}^{\mathbf{ag}} \rightsquigarrow \lambda P_{et}.\lambda\mathcal{P}_{\epsilon t}.\lambda\mathbf{e}_\epsilon.\ \mathcal{P}(\mathbf{e}) \wedge \mathbf{ag}(\mathbf{e}) = \sigma x.\ P(x)$

(61) $\textit{boys} \rightsquigarrow \lambda x_e.\ {}^*\textsc{boy}(x)$

(62) $\textit{PAST} \rightsquigarrow \lambda\mathcal{P}_{\epsilon t}.\ \exists\mathbf{e}_\epsilon(\mathcal{P}(\mathbf{e}) \wedge \mathbf{runtime}(\mathbf{e}) \prec \mathbf{now})$

(63) $\begin{array}{l} \exists\mathbf{e}_\epsilon(\textsc{recite}(\mathbf{e}) \wedge \mathbf{th}(\mathbf{e}) = \textsc{the-raven} \wedge \\ \mathbf{ag}(\mathbf{e}) = \sigma x.\ {}^*\textsc{boy}(x) \wedge \\ \mathbf{runtime}(\mathbf{e}) \prec \mathbf{now} \wedge \\ \mathbf{linear.order}(\{\mathbf{e}' \leq \mathbf{e} : \mathbf{atom}(\mathbf{e}')\}) \wedge \\ |\,\{x_e \leq {}^{**}\mathbf{ag}(\mathbf{e}) : \mathbf{atom}(x)\}\,| > 1 \wedge \\ \forall\mathbf{e}' \leq \mathbf{e}(\mathbf{atom}(\mathbf{e}') \rightarrow \mathbf{atom}({}^{**}\mathbf{ag}(\mathbf{e}')))) \end{array}$

(64)
$$\begin{array}{lcccccc} \mathbf{e} & = & \mathbf{e}_1 & \oplus & \mathbf{e}_2 & \oplus & \ldots \\ & & \mathbf{atom}(\mathbf{e}_1) & & \mathbf{atom}(\mathbf{e}_2) & & \ldots \\ & & \mathbf{runtime}(\mathbf{e}_1) & \prec & \mathbf{runtime}(\mathbf{e}_2) & \prec & \ldots \\ \textit{the.boys} & = & \textit{boy}_1 & \oplus & \textit{boy}_2 & \oplus & \ldots \\ & & \mathbf{atom}(\textit{boy}_1) & & \mathbf{atom}(\textit{boy}_2) & & \ldots \\ & & \mathbf{ag}(\mathbf{e}_1) = \textit{boy}_1 & & \mathbf{ag}(\mathbf{e}_2) = \textit{boy}_2 & & \ldots \end{array}$$

In contrast, (65) is ambiguous: *one by one* can target either the **ag** or the **th** role because they are both associated with plural individuals.

(65) The$^{\mathbf{ag}}$ boys recited the$^{\mathbf{th}}$ poems one by one$_{\mathbf{ag/th}}$.

The fact that θ-role cumulative closure is built into the meaning of *one by one* allows us to account for the fact that *one by one* can target DPs headed by *each*.

(66) One by one$_{\mathbf{ag}}$, each$^{\mathbf{ag}}$ boy recited 'The Raven'$^{\mathbf{th}}$

For simplicity, let us give *each* an encapsulated treatment: *each* simultaneously distributes over events and individuals.

(67) $each^{\mathbf{ag}} \rightsquigarrow \lambda P_{et}.\lambda \mathcal{P}_{\epsilon t}.\lambda \mathbf{e}_{\epsilon}.$
$\forall \mathbf{e}' \leq \mathbf{e}(\mathbf{atom}(\mathbf{e}') \rightarrow \mathcal{P}(\mathbf{e}')) \wedge$
$\mathbf{ag}[\{\mathbf{e}' \leq \mathbf{e} : \mathbf{atom}(\mathbf{e}')\}] = \{x_e : \mathbf{atom}(x) \wedge P(x)\}$

- $\theta[\mathbf{E}] = X$ abbreviates $X = \{\theta(\mathbf{e}) : \mathbf{e} \in \mathbf{E}\}$, i.e., the set X is the image of the set $\mathbf{E}$ under the function θ

(68) $\exists \mathbf{e}_{\epsilon}(\forall \mathbf{e}' \leq \mathbf{e}(\mathbf{atom}(\mathbf{e}') \rightarrow$
$\text{RECITE}(\mathbf{e}') \wedge \mathbf{th}(\mathbf{e}') = \text{THE-RAVEN}) \wedge$
$\mathbf{ag}[\{\mathbf{e}' \leq \mathbf{e} : \mathbf{atom}(\mathbf{e}')\}] =$
$\{x_e : \mathbf{atom}(x) \wedge \text{BOY}(x)\}$
$\wedge \mathbf{runtime}(\mathbf{e}) \prec \mathbf{now} \wedge$
$\mathbf{linear.order}(\{\mathbf{e}' \leq \mathbf{e} : \mathbf{atom}(\mathbf{e}')\}) \wedge$
$|\{x_e \leq {}^{**}\mathbf{ag}(\mathbf{e}) : \mathbf{atom}(x)\}| > 1 \wedge$
$\forall \mathbf{e}' \leq \mathbf{e}(\mathbf{atom}(\mathbf{e}') \rightarrow \mathbf{atom}({}^{**}\mathbf{ag}(\mathbf{e}'))))$

4 Conclusion

- *one by one* is an event modifier that targets a plural participant in the event it modifies
- *one by one* distributes over this participant by targeting its θ-role
- the resulting distributive dependencies are different from the distributive dependencies introduced by items like *each*

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