

Distance distributivity and the semantics of indefinite noun phrases

Raj Singh and Ida Toivonen*
Carleton University

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1 Overview

- Binominal *each*: The students ate an apple **each**.
- **New finding:**
People prefer *The students ate **one** apple each* over *The students ate **an** apple each*.
- People prefer “numeral noun each” over “a/an noun each”, although both are generally fine (Hessel et al. 2015)
- Our claim: NPs with a/an N in object position can have an incorporation interpretation.

(1) *read a book*

(2) *eat a cookie*

- In other words, *John read a book* has two interpretations:
 - (i) There is a book such that John read it. (“normal” interpretation)
 - (ii) John engaged in book-reading. (incorporation interpretation)
- The incorporation interpretation is not compatible with a distributive interpretation.
- In an example like (3), there can be a slight garden path effect (you start with the incorporation reading) which means it is not as good as (4):

(3) The boys watched a movie each.

(4) The boys watched one movie each.

- need to provide: (i) the set of readings assigned to (3) without *each*, (5), and (ii) what binominal *each* contributes to the sentences it occurs in

(5) The boys watched a movie.

- it turns out that there are interesting generalizations relating (i) and (ii), which again lead us to the semantics of indefinites
- more general characterization of distribution/preferences of binominal *each*:

(6) **Distribution:**

- (i) Binominal *each* must attach to an indefinite noun phrase;
- (ii) Within this class, there is a preference to attach to NPs containing numerals than NPs containing the indefinite article.

- we will begin with (i), and use it to help make sense of the numeral vs. indefinite result

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2 Binominal *each*

- (7) The students read a book each.
- (8) We'll paint a few rooms each.
- (9) Susan and Peter tricked two children each.
- Distance distributivity
 - Different from other uses of *each* (Safir and Stowell 1988, Zimmermann 2002b, Kobuchi-Philip 2006, Milačić 2014, and others)
- (10) **binominal each:** The boys carried a table each.
- (11) **floated each:** The boys each carried a table.
- (12) **prenominal each:** Each boy carried a table.
- (13) Binominal *each* does not occur with intransitives:
- a. *The boys left each.
 - b. The boys each left.
 - c. Each boy left.
- (14) Binominal *each* must occur with an indefinite NP:
- a. The boys kicked {a/one/*the/*every/*no} rock each.
 - b. The boys each kicked {a/one/the/every/no} rock.
 - c. Each boy kicked {a/one/the/every/no} rock.
- The subject is a plural (definite) NP; the object is an indefinite NP
 - The “sorting key” (NP1) does not have to be a subject, and the “distributed share” (NP2) does not have to be an object (terms: Choe 1987)
- (15) Students have to sell a modest quota of three books each. (www)
- (16) With one smile each, the three men disappears from the apartment, leaving the door open to reveal the mess after her fight to survive. (www)
- (17) If u were going to a twin party then I would get the twins a present each. (www)
- in all languages we know of, markers of distance distributivity are restricted to marking indefinite NPs
 - thus, always express: $\forall x \exists y R(x, y)$
 - vary in how they mark the indefinite¹
- (18) Variation
- a. English: Add *each* to indefinite object
 - b. Slavic: Add preposition *po*: *the boys read po book* (e.g., Pesetsky 1982, Kuznetsova 2005, Przepiórkowski 2008)
 - c. Hungarian: Reduplicate the numeral: *the boys read one-one book* (e.g., Farkas 1997)
- Reduplication as a marker of distributivity occurs in a variety of languages and language families; for example, *Finno-Ugric* (e.g., Hungarian), *Algonquian* (e.g., Cree (Junker 2000)), *Iroquoian* (e.g., Lakhota (Rood and Taylor 1996)), *Salish* (e.g., Lushootseed (Urbanczyk 2001), St'at'imcets (Matthewson 2000)), *Mayan* (e.g., Chol (Alvarez 2011)), *Dravidian* (e.g., Kannada (Anderson 2012)) and Telugu (Balusu 2006)), *Tibeto-Burman* (e.g., Ao (Gowda 1975)), *Bantu* (e.g., Kanyok (Mukash-Kalel 1982)). Gil (1982, 2013) and Moravcsik (1978) offer more examples.

¹They also vary in the domains that the universal quantifier can quantify over: just individuals (e.g., English), individuals and events/times/situations (e.g., German), or individuals, events/times/situations, and worlds (Russian). See Milačić et al. (2015) for a more specific typological characterization.

- (19) **Typological Generalization:** Across languages from different language families: distance distributivity is expressed by adding morphology to indefinite NPs (NB: the added morphology is typically not identical with the language’s distributive quantifier)
- lots of literature on the semantics of binominal *each*: Brasoveanu and Dotlačil (2012), Champollion (2012), Choe (1987), Oh (2006), Przepiórkowski and Patejuk (2013), Safir and Stowell (1988), Zimmermann (2002a), Cable (2014), Dotlačil (2012), Kobuchi-Philip (2006), Bauman et al. (2012), Blaheta (2003), Boeckx and Hornstein (2005)
 - however, so far as we can tell, none of that literature derives (19)
 - diagnosis: they focus on finding a semantics of binominal *each* as an operator
 - we will suggest instead that *each* is a bound-variable²
 - our proposal builds on the observation that the sentence without *each* has a meaning that can be unambiguously expressed by adding *each*, namely, the distributive meaning
 - suggestion: reuse all relevant semantic machinery needed to get the distributivity meaning without *each*; *each* just disambiguates by marking the underlying quantifier-dependence
 - Binominal *each* seems to pair members of the subject set with members of the object set: capture this ‘pairing’ explicitly in the underlying semantic representation with appeal to General Skolem Functions
- (20) Marking quantifier-dependence
- $[\forall x : \text{boy}(x)][\exists y : \text{table}(y)](\text{lifted}(x, y))$
 - General Skolem Functions: $\exists f[[\forall x : \text{boy}(x)](\text{lifted}(x, f(x, \text{table})))]$
- for any choice of boy x , f maps x to a table $f(x, \text{table})$; the sentence is true so long as there is a mapping such that each boy lifted the table that they’re mapped to
 - suggestion: the variable x in $f(x, \text{table})$ can be realized as \emptyset , in which case *the boys lifted a table* is ambiguous, or realized as *each* in English
 - other languages: spelled out as reduplicated numeral, or as some other lexical item unrelated to distributive quantifier in the language (e.g., Slavic *po*)
- (21) Readings of *the boys lifted a table*
- Collective/referential: the boys collectively lifted a table: $\text{lifted}(\text{max}([\text{boys}], f(\text{table}))$
 - Distributive/quantificational: each boy lifted a table: $[\forall x : \text{boy}(x)](\text{lifted}(x, f(x, \text{table})))$
- we suggest that (21) has another reading: $[\forall x : \text{boy}(x)][x \text{ engaged in table-lifting}]$

²In fact, there is evidence that *each* is subject to Condition A, e.g., **the boys believe Mary lifted a table each*. See e.g., Hudson 1970, Kayne 1981, Burzio 1986.

An aside: The distributivity hierarchy

- We think that our Skolem analysis can make sense of another empirical generalization: speakers judge binominal *each* to be “more distributive” than other uses of *each*, and also *every* and *all* (Hessel et al. 2016 and also Tunstall 1998)
- Two on-line voluntary, anonymous questionnaire studies, forced choice.
- Questions:
 - In which case is *the boys fed the same dog* more likely to be true?
 - In which case is *the students ordered a pizza together* more likely to be true?
- Options, examples:
 - Every boy fed a dog.
 - The boys fed a dog each.
- Distributivity hierarchy, ranked from distributive to collective:
binominal *each* > prenominal *each* > *every* > floated *each* > *all*
- Our thoughts on why binominal *each* is the most distributive:
binominal *each* does not allow wide-scope of the indefinite, and this follows from our analysis

3 Numerals vs. indefinite articles

- Speakers seem to prefer numerals (22) over an indefinite article (23) in the binominal each DP.

- (22) a. The nurses treated one patient each.
 b. The chefs prepared seven dishes each.
- (23) a. The nurses treated a patient each.
 b. The pilots flew a plane each

3.1 Our English study: Methods

- We conducted three different experiments (grammaticality questionnaires)
- The questionnaires had 28, 43, and 86 participants (actually more; we are only concerned with the native speakers of English here). The studies had different stimuli and slightly different designs, but the results were the same. We report only on the third study here.
- SurveyMonkey, on-line questionnaire. Anonymous, no compensation for participation.
- First question: Is English your first language?
- 14 target sentences, 30 fillers.

3.2 Our English study: Results

- **69** out of 86 participants (80%) preferred numerals over indefinites; 17 did not (**7** had the opposite preference, and **10** had no preference).
- Binomial test for proportions significant at the 99% level, indicating a strong preference for numerals over indefinites.

- (24) All examples with indefinites and all examples with numerals:

Condition	$M(SD)$	95% CI
Indef	5.18 (1.68)	[4.82, 5.54]
NUM	5.86 (1.42)	[5.56, 6.16]

The researchers published seven papers each; The nurses treated one patient each. M=6.21; SD=1.34
The pilots flew a plane each; The girls lifted a box each. M=5.05, SD=1.84
Welch t-test $p < 0.01$

4 Indefinite objects may have incorporation semantics

- Proposal: *John read a book* has two interpretations:
 - (i) There is a book such that John read it. (“normal” interpretation)
 - (ii) John engaged in book-reading. (incorporation interpretation)
- Some examples of real incorporation (morphological incorporation):

(25) *pitsituvunga* (Inuktitut, Johns 2007)
pitsi-tu-vunga
dried.fish-consume-intrans.indic.1s ‘I’m eating dried fish.’

(26) *anin ədtiydarip̄ten* (Sora, Donegan and Stampe 2002)
anin əd-tiy-dar-ip̄-ten
he not-give-rice-me-3past ‘He didn’t give me rice.’

- van Geenhoven (1998): in sentences like *every man loves a woman*, the narrow reading is a result of semantic incorporation
- there are also other suggestions in the literature that indefinites might have an incorporation semantics even in absence of morphosyntactic incorporation (e.g., Chung and Ladusaw 2004, Carlson 2006, López 2012)
- Why do people like *read one book each* better than *read a book each*?
- **Our proposal:** The incorporated reading is not compatible with binominal *each*, which requires the members of the set denoted by the object to be picked out individually. Reference to individuals (or sets of individuals) is not possible under the incorporation reading. If an indefinite NP receives an incorporated reading, listeners must repair when they get to *each* (garden path).

Carlson 2006:

- Carlson lists six + one stable properties of the semantics of incorporation (Carlson 2006).
- Most of them seem to hold for indefinite NPs as well.
- We refer to a/an NPs as a-NPs below to distinguish them from other indefinite NPs (*some, one, any...*)
- We go through Carlson’s criteria in sections 4.1–4.7

4.1 The incorporated nominal is interpreted as an indefinite

- “The incorporated nominal is interpreted as an indefinite, rather than as a definite or some quantified type of noun phrase.”

4.2 The indefinite is non-specific, rather than specific in import

- A-NPs can be interpreted as non-specific, and *are* interpreted as non-specific under the incorporated meaning.

4.3 The indefinite is interpreted as a narrow-scope indefinite only

- “The indefinite is interpreted as a narrow-scope indefinite only, showing no scoping interactions with other logical operators in the same sentence that is typical of syntactically-expressed indefinites.”
- A-NPs can be interpreted with narrow scope, and are interpreted this way under incorporation.

4.4 The incorporated nominal is interpreted as an existential

- “The incorporated nominal is interpreted as an existential, and not as a generic indefinite – it lacks the ‘universal’ flavor of true generics.”
- The normal interpretation of a-NPs is as existentials.

4.5 The verbs that allow for incorporation are stage-level verbs

- “The verbs that allow for incorporation are stage-level verbs, individual-level stative predicates like *hate* or *know* are systematically excluded.”
- stage-level: temporal stage, individual-level: generally true for the individual
- A-NPs can be part of stage-level predicates (*he ate a burger*, *he imitated a lawyer*); so far as we can tell, the intuition about an incorporated meaning for a-NPs only arises with stage-level predicates

4.6 The incorporated nominal is number-neutral in interpretation

- “The incorporated nominal is number-neutral in interpretation, though in most languages with a singular-plural distinction the count noun forms may easily be taken for singulars.”
- It seems like a-NPs are naturally interpreted as singulars.
- *John read a book* is often understood as asserting that John read exactly one book
- However, the singular interpretation can be overridden, or at least it’s not as important as when you say “one N”.
- It has been argued (e.g., Heim 1991) that the singular interpretation is merely an implicature (e.g., *John read a book last week; in fact, he read two...*).
- Difference between *John read a book* and *John read one book*: the exactly-one implicature is stronger with the numeral than with the indefinite
- It is well-known that the implicatures of numerals are more robust than other implicatures (e.g., see Chemla and Singh 2014a,b for an overview)

(27) In the summers, I love lying on the beach reading a book.

(28) I hope I’ll make a friend today.

Contrast with:

(29) # In the summers, I love lying on the beach reading one book.

(30) # I hope I’ll make one friend today.

- In the examples with *one*, the exact quantity is more important, i.e., sentences containing numerals seem to be naturally used to answer a *how many* question
- This is especially clear in light verb constructions.

(31) Susie might have a drink tonight.

(32) I love taking a nap.

(33) I think I’ll have a swim in the pool.

- In light verb constructions, the V+a-NP can be replaced by a verb (to drink, to nap, to swim).
- It seems strange to argue with someone about the number of entities satisfying the a-NP in light verb constructions:

A: I had a drink last night.

B: # What are you talking about? You had three!

- B’s response would have been more reasonable had A said *I had one drink last night* (stronger implicature that it was only one)
- Also: *Do you want to go for a drink?* vs. *Do you want to go for one drink?* — The latter implies *just one drink*

4.7 The domain of the incorporated noun is usually restricted

- The restrictions can be grammatical: formal/syntactic restrictions on the noun or the verb
- or semantic: “some ‘familiar’ cultural significance be accorded the action whether there is semantic enrichment of not”
- Maybe something like *read a book* is more likely to take on an incorporation meaning than *punch a lightbulb*?

4.8 Summary

- It seems that a-NPs (e.g., *a book*) trivially fulfill many of the criteria of incorporation semantics, and can be argued to at least sometimes fulfill the remaining criteria.

5 Swedish

5.1 Binominal *var* in Swedish.

- (34) Vi kontaktade en resebyrå **var**.
we contacted a travel.agency each
'We contacted a travel agency each.'
- (35) Dom köpte två hundar **var**.
they bought two dogs each
'They bought two dogs each.'

- The word *var* is equivalent to binominal *each* in (34–35).
- The indefinite article *en/ett* is the same as the number *one* in Swedish.
- Example (34) could also be translated as 'We contacted one travel agency each.'

5.2 Swedish survey: Design

- Grammaticality questionnaire on SurveyMonkey.
- Instructions: rate examples according to naturalness, 1-5.
- 428 participants.
- Target sentences spread out over four surveys so that the same participant would not see the same lexical items in different frames.

5.3 Binominal *var*: singular and plural

- Like in English, speakers prefer numeral examples over indefinite article examples: they prefer (35) over (34). (Recall that *en/ett* is the indefinite article and the number *one*.)
 - However, in addition to binominal *var*, Swedish has another equivalent of binominal *each*:
- (36) Vi läste varsin bok.
we read each.POSS book
'We read a book each.'

- The word *varsin* is (at least seemingly) composed of *var* 'each' and the third person reflexive possessor *sin*.
- Speakers prefer (36) over (34).
- The *varsin* form is only marginally acceptable in plurals.
- Overall results from our survey:

	example	average rating (standard deviation)
(a) <i>varsin</i>	Vi läste varsin bok.	4.7 (0.76)
(b) SG + <i>var</i>	Vi läste en bok var.	4.1 (1.24)
(c) PL + <i>var</i>	Vi läste två böcker var.	4.7 (0.82)

- the difference between (a) *varsin* and (b) SG + *var* is significant (p<.01)
- the difference between (b) SG + *var* and (c) PL + *var* is significant (p<.01)
- the difference between (a) *varsin* and (c) PL + *var* is not significant (p=.33)

So far: pretty much the same as English, except the indefinite article and the number *one* are homophonous in Swedish, and Swedish has the additional *varsin* form.

5.4 Pseudo-incorporation in Swedish

- Swedish allows what has been called ‘pseudo-incorporation’: a plain singular noun is allowed as an object, although singular nouns normally require a determiner.

(37) Dom har köpt ett hus.
 they have bought a house
 ‘They have bought a house.’

(38) Dom har köpt hus.
 they have bought house
 ‘They have bought a house.’ (Or “They have house-bought”)

- Pseudo-incorporation examples such as (38) have incorporation semantics, as outlined in Carlson (2006); see section 4 above.
- Not all verb+object combinations allow pseudo-incorporation in Swedish. Compare the examples in (39) to the examples in (40).

(39) a. Vi tog bil till festen.
 we took car to party
 ‘We took a car to the party.’
 b. Dom såg film tillsammans.
 They watched movie together
 ‘They watched a movie/movies together.’

(40) a. *Ni hittade ledtråd.
 you.PL found clue
 (intended: ‘You found a clue’)
 b. *Hon dansade med kompis.
 she danced with friend
 (intended: ‘She danced with a friend.’)

- The judgements are Ida’s, supported by collocation searches on google. We also tested the following examples in the questionnaire:

(41)	Maja och Kalle köpte en hund. Maja and Kalle bought a dog. ‘Maja and Kalle bought a dog.’	mean: 4.90 , median: 5
(42)	Sanna och Putte köpte hund. Sanna and Putte bought dog. ‘Sanna and Putte bought a dog.’	mean: 4.56 , median: 4
(43)	Familjen köpte bil. Family.the bought car. ‘The family bought a car.’	mean: 4.36 , median: 5
(44)	*Hanna och Petter kritiserade bok. Hanna and Petter criticized book ‘Hanna and Petter criticized a book/books.’	mean: 1.42 , median: 1

5.5 Swedish pseudo-incorporation and binominal *var*

- Examples that allow pseudo-incorporation receive significantly lower ratings for examples with singular NP + *var* than examples that do not allow pseudo-incorporation.

<i>each</i>	allows incorporation	rating	does not allow incorporation	rating
<i>varsin</i>	ex. Vi köpte varsin hund.	4.73	ex. Vi kritiserade varsin bok.	4.66
SG + <i>var</i>	ex. Vi köpte en hund var.	3.93	ex. Vi kritiserade en bok var.	4.15
PL + <i>var</i>	ex. Vi köpte två hundar var.	4.71	ex. Vi kritiserade två böcker var.	4.59

<i>each</i>	allows incorporation.	doesn't allow incorporation	significant
<i>varsin</i>	M=4.73; median=5; SD=0.72	M=4.66; median=5; SD=0.82	no
SG + <i>var</i>	M=3.93; median=5; SD=1.32	M=4.15; median=5; SD=1.21	yes
PL + <i>var</i>	M=4.71; median=5; SD=0.77	M=4.59; median= 5; SD=0.95	no

- When pseudo-incorporation is possible, *en X var* ‘an X each’ is rated lower than when pseudo-incorporation is not possible.
- T-tests for incorporation VPs:

INCORP.	averages	significant
<i>varsin</i> — SG + <i>var</i>	4.73 — 3.93	yes
<i>varsin</i> — PL + <i>var</i>	4.73 — 4.71	no
SG + <i>var</i> — PL + <i>var</i>	3.93 — 4.71	yes

- T-tests for non-incorporation VPs:

NON-INCORP	averages	significant
<i>varsin</i> — SG + <i>var</i>	4.66 — 4.15	yes
<i>varsin</i> — PL + <i>var</i>	4.66 — 4.59	no
SG + <i>var</i> — PL + <i>var</i>	4.15 — 4.59	yes

- Caveat: We have not yet tried to replicate the Swedish study.
- The study included six incorporable and six non-incorporable V-NP combinations.
- Examples (45–46) were excluded from our analysis, because we were surprised by the very low rating for (46).
- However, note that the low rating for (46) is not problematic for our hypotheses.

- (45) Ken och Sandra tog varsitt flyg hem. mean:**4.59**, median:**5**
 Ken and Sandra took each.their plane home
 ‘Ken and Sandra took a flight/plane each home.’
- (46) Ken och Sandra tog ett flyg var hem. mean:**1.84**, median:**1.5**
 Ken and Sandra took a plane each home
 ‘Ken and Sandra took a flight/plane each home.’

- The VPs that allow pseudo-incorporation differ from the verbs that don’t allow pseudo-incorporation, even though they pattern similarly in general (cf. the last two tables).
- The VPs that allow pseudo-incorporation do not work so well with SG + *var* (although they are grammatical). We argue that this is because such examples are especially likely to be interpreted with incorporation semantics (as evidenced by the fact that they allow pseudo-incorporation).
- In other words: “we house-bought” is closer at hand than “we book-criticized”, even when an indefinite article is present (when the object is not formally pseudo-incorporated)
- We assume that direct objects with indefinite articles can be semantically incorporated in Swedish as well as in English, even though Swedish also has the possibility of formal (morphological) pseudo-incorporation.

An aside: Some more stuff about Swedish universal quantifiers & distributivity

- (47) Alla studenterna läste en bok.
all students.the read a book.
'All the students read a book.'
- (48) Varje student läste en bok.
every/each student read a book
'Every student read a book.'
- (49) Varenda student läste en bok.
every/each student read a book
'Every student read a book.'
- (50) Studenterna läste var och en en bok.
students.the read each and one a book
'The students each (and one) read a book.'
- (51) Studenterna läste en bok var.
students.the read one book each
'The students read one book each.'
- (52) Studenterna läste varsin bok.
students.the read each.POSS book
'The students read one book each.'

- Distributivity hierarchy (according to forced-choice survey, 150 respondents), ranked from more distributive to more collective:

$$\text{varsin} > \text{binominal var} > \left\{ \begin{array}{l} \text{varje} > \text{floated var och en} \\ \text{varenda} \end{array} \right\} > \text{alla}$$

6 Summary

- We proposed that various puzzles in distance distributivity can be resolved by a better understanding of the semantics of indefinite noun phrases
- We captured the restriction to indefinites by appealing to Skolemized Choice Functions.
- Within this class of acceptable hosts of binominal *each*, speakers prefer NPs with a numeral over NPs with an indefinite article with binominal *each*;
in other words: *We ate three apples each* is preferred over *We ate an apple each*.
- We argue that this is because objects with indefinite articles (a/an) can be semantically incorporated in English.
- In a sentence like *they caught a fish each*, an incorporation reading is possible (though not necessary) up until *each*. If the listener gets the incorporation interpretation, they need to repair when they get to *each*.
- Objects with numerals are not compatible with incorporation semantics because they are not compatible with a number-neutral interpretation.
- van Geenhoven (1998) has already proposed (for different reasons) that indefinite objects in English can be semantically incorporated.
- verb + *a/an*-NPs (*read a book*, *eat a cookie*) are compatible with typical characteristics of incorporation Carlson (2006)
- Swedish allows pseudo-incorporation for some verb-object combination; e.g., *köpa hus*, *köra bil* (*buy house*, *drive car*).
- Verb-object combinations that allow pseudo-incorporation are rated significantly lower with post-object *var* (\sim binominal *each*) than verb-object combinations that do not allow pseudo-incorporation.
- We propose that this is because verb-object combinations that allow pseudo-incorporation in general easily allow an incorporation reading.

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A Distance distributivity meanings and their compositional derivation

(53) The boys lifted a table each

- Milačić et al. (2015): the truth-conditions above – as well as the constraints alluded to in the main text – are perhaps transparently captured with a Skolemized Choice Function treatment of indefinites (for Choice-Functional treatments, see e.g., Reinhart 1997, Winter 1997, Kratzer 1998, Matthewson 1999, Chierchia 2001, Schlenker 2006)
- that is, we argue that the meaning above can be captured if the logical form of 53 is: $\exists f[[\forall x : boy(x)][lifted(x, f(x, table))]]$
- how is this derived?
- *lift* is a transitive predicate: $lift(x, y)$ (or, more accurately, $\lambda y.\lambda x.lift(x, y)$)
- in 53, $y = f(x, table)$ (this is the indefinite object *a table each*), and the variable in $f(x, table)$, as well as the first argument of *lift*, is bound by the higher universal quantifier
- challenge: explain how the universal quantifier, and the complex second argument of *lift*, are derived
- consider the second argument $f(x, table)$
- we want this to be the denotation of *a table each*
- f is a variable over General Skolem Functions, which we assume here gets existentially closed in matrix position
- a *General Skolem Function* is a function which takes k individual arguments x_1, \dots, x_n , and a predicate P , and returns in individual in P : $f(x_1, \dots, x_k, P) \in P$; in the above, $f(x, table)$ maps individual x to a table (e.g., Schlenker 2006)
- we assume that indefinites denote variables over k -arity General Skolem Functions, $k \geq 0$ (e.g., Winter 2004, Schlenker 2006, Steedman 2012)³
- the universal quantifier $[[\forall x : boy(x)]]$ is generated by the subject *the boys D*, where D is a ‘distributive’ operator; see e.g., the treatment of distributivity in Heim et al. (1991)

(54) Deriving the universal quantifier

- a.. $[[boys]] = \{b_1, b_2, b_3, b_1 \oplus b_2, b_1 \oplus b_3, b_2 \oplus b_3, b_1 \oplus b_2 \oplus b_3\}$
- b.. $[[the boys]] = b_1 \oplus b_2 \oplus b_3$ (*the* selects the maximal element in its input; e.g., Link 1983)
- c.. $[[the boys D]] = \lambda P_{et}.\forall x \bullet \sqsubseteq b_1 \oplus b_2 \oplus b_3 : P(x)$ ⁴

³See Milačić et al. (2015) for evidence that k is upper-bounded by 1, and that the binder must be local.

⁴ $[[D]] = \lambda X_e.\lambda P_{et}.\forall x \bullet \sqsubseteq X : P(x)$, where $\bullet \sqsubseteq$ is the ‘atomic part-of’ relation (see e.g., Heim et al. 1991, Milačić et al. 2015).