Atoms and Sets:  
A Characterization of Semantic Number

draft 13/8/99

Yoad Winter
Technion/UiL OTS

Abstract

This paper introduces a novel approach to the semantics of plurals that is not based on the traditional distributive/collective distinction between predicates. Rather, the semantic number of nouns, verbs and adjectives is classified according to their behaviour under replacement of a plural determiner (e.g. all, plural no) by its singular counterpart (e.g. every, singular no). It is proposed that predicates that are insensitive to this replacement range over atomic entities, whereas number sensitive predicates range over sets of such atoms. This model-theoretic property, together with morpho-syntactic number of predicates and the quantificational/non-quantificational distinction between noun phrases, governs the availability of collective interpretations. The emerging system offers a general solution to some long-standing problems concerning the differences between every, all and simple plural definites.

1 Introduction

In a widely cited work, Vendler (1967:70-76) points out some important differences between the singular quantifier words every and each and the plural word all. The contrast that Vendler discusses can be illustrated using the following sentences.

\[
(1) \begin{align*}
\text{a. All the students} & \quad \{ \text{met/gathered/lived together} \} \\
\text{b. *Every/each student} & \quad \{ \text{are (is) similar} \} \\
\text{c. The students} & \quad \{ \text{numeros a good team} \} 
\end{align*}
\]

The all noun phrase in (1a) allows an intelligible interpretation to the sentence, similarly to the simple plural definite the students in (1c). By contrast, the singular words every and each in (1b) lead to unacceptable sentences.

In these examples, it may seem that the semantic analysis of the contrast between every/each and all can be quite straightforward. Some authors, including among others Vendler (1967:74-75) himself and Higginbotham (1980), propose that all is semantically different from each and every in being intrinsically "collective". However, this line of account is insufficient for a couple of reasons. First, as Dowty (1987) shows, with some collective predicates all behaves quite like every and each, and not like the plural definite. Consider for instance the following examples by Dowty.

\[
(2) \begin{align*}
\text{a. *All the students} & \quad \{ \text{are (is) numeros a good team} \} \\
\text{b. *Every/each student} & \quad \{ \text{are (is) numeros a good team} \} \\
\text{c. The students} & \quad \{ \text{are (is) numeros a good team} \} 
\end{align*}
\]
(3) All the students voted to accept the proposal.

In (2a), the *all* sentences are unacceptable like the corresponding sentences with *every* and *each* in (2b), and they are clearly interpreted differently from the acceptable sentences in (2c) with plural definites. Also in (3), *all* patterns with *every* and *each* and not with the simple definite. The sentence means that *each* student voted for the proposal. Therefore, the claim it makes is logically stronger than the claim that the *students* voted to accept the proposal, which can also be true if some students did not vote for the proposal. These observations by Dowty show that if the account of the contrast in (1) is stated by appealing to an inherent collectivity feature of *all*, it becomes a mystery why *all* loses its collectivity with the predicates in (2) and (3).

A second problem for the "collective *all*" hypothesis is that similar differences to the ones between *all* and *every*/*each* in (1) can be observed with other pairs of plural and singular determiners. For instance, consider the contrast in (4) below between plural *no* and singular *no*.

\[
(4) \begin{cases}
  \text{a. No students} & \text{met/gathered/lived together} \\
  \text{b. *No student} & \text{are (is) similar}
\end{cases}
\]

Also in similarity to universal quantifiers, singular and plural *no* do not contrast when they combine with the predicates in (2)-(3). The following examples illustrate that.

\[
(5) \begin{cases}
  \text{a. *No students} & \text{are (is)} \\
  \text{b. *No student} & \text{numerous a good team}
\end{cases}
\]

(6) No students voted to accept the proposal.

Similarly to (2), the sentences in (5a) do not differ in their acceptability from their counterparts with singular *no* in (5b). Further, in parallelism to the *all*/*every* equivalence in (3), sentence (6) means the same as its counterpart with the singular noun phrase *no student*. Similar observations hold for other plural/singular pairs of noun phrases like *at least two students/*more than one student* and *many students/*many a student*. In all these cases the plural NP shows collectivity with predicates as in (1) but fails to do so with the predicates in (2)-(3), while the singular NP does not show collectivity in either of the cases. Thus, the problem of *every*/*each* and *all* is not an isolated problem of different modes of universal quantification in natural language. Rather, it points to a more general contrast between singular noun phrases and plural noun phrases. An account that simply stipulates that *all*, plural *no*, *at least two*, *many* etc. are "collective" obviously misses this generalization.

To sum up, there are three mutually dependent contrasts that the theory of plurals has to explain:

1. The contrast between predicates with respect to their "collectivity potential", as observed by comparing (1a) to (2a) and (4a) to (5a).
2. The contrast between plural NPs like *all the/no students* as in (1a) and (4a), and singular NPs like *every/no student* as in (1b) and (4b).
3. The contrast between "quantificational" NPs like *all the students* in (2a) and "non-quantificational" NPs like *the students* in (2c).
The theory proposed in this paper explains these contrasts by appealing to a simple model-theoretic distinction between meanings of natural language expressions: the distinction between denotations that range over atomic entities and denotations ranging over sets of such entities. This difference in semantic number is used as the key for explaining the difference between two classes of natural language predicates (nouns, verbs and adjectives). Atom predicates are predicates like numerous and vote, which show equivalence (in truth-conditions or acceptability) between sentences with plural determiners (e.g. all, plural no) and the corresponding sentences with singular determiners (e.g. every/each, singular no). Set predicates are predicates like meet and be similar, which are sensitive to the morphological number of the noun phrase they combine with. The proposed theory accounts for the three kinds of contrasts summarized above using the following three general assumptions.

1. The denotation of lexical predicates (unspecified for morphological number) ranges over atoms or over sets according to the proposed new typology of predicates.

2. The denotation of number inflected predicates is computed using their lexical denotation and their number feature so that singular predicates end up ranging over atoms and plural predicates range over sets.

3. Noun phrases that have a non-quantificational interpretation can also be interpreted using an operator that maps sets to atoms.

The first claim accounts for why atom predicates are more restricted in their ability to show collectivity than set predicates. The second claim explains why morpho-syntactic plurality is a necessary condition for collectivity with count nouns in English. The third claim predicts the collective behaviour of non-quantificational NPs with atom predicates, vis à vis quantificational NPs, which are univocally distributive with such predicates.

The system developed following these claims explains contrasts like the one between every/each and all in (1) not as a lexical semantic difference between these items. Pairs like every and all or singular no and plural no are treated as lexical synonyms. Their different number features are not semantically interpreted but the number features of the nouns they select for do. Because plural nouns range over sets of atoms, their semantic composition involves a type mismatch with determiners, which all lexically range over atoms. The resolution of this mismatch, using a type shifting procedure (cf. Partee and Rooth (1983)), results in collectivity with plural NPs. Singular NPs do not show this type mismatch and consequently their meaning is unambiguously atomic (distributive). In developing this system, the paper thus defines and characterizes a semantic number feature of natural language expressions and analyzes its relationships with morpho-syntactic number.

Section 2 reviews some elementary formal semantic notions that will be useful for the rest of this article. Section 3 argues against the distributive/collective distinction as a criterion for deciding on the formal semantic number of predicates. Instead, the section defines and exemplifies the proposed typology of atom predicates and set predicates. Section 4 addresses the relationships between the atom/set classification of lexical predicates and the effects of the number feature on inflected predicative forms. Section 5 discusses the difference between quantificational NPs and non-quantificational
NPs, and its effects on their semantic number. The proposed general framework is summarized in section 6. Section 7 concludes the article with some problems for further research. An appendix formally defines the type shifting operator responsible for collectivity with plural determiners and some of its consequences for the linguistic predictions of the system.

2 Formal preliminaries

This section briefly reviews some principles of model-theoretic semantics that are necessary for the developments in subsequent sections. The distinction between atomic entities and plural entities is introduced. This distinction, which is foundational to semantic theories of plurality, is contrasted with the standard theory of atomic quantification in natural language: the theory of generalized quantifiers as developed, among others, by Barwise and Cooper (1981). An integration of the two theories is obtained by the proposal in the following sections, and is more formally developed elsewhere (Winter 1998a, 1998b: ch. 5).

2.1 Atoms and sets

Virtually all versions of model-theoretic semantics contain a domain of entities (individuals) in the model of discourse. This domain is standardly referred to using the letter $E$. The denotations of natural language expressions are defined on top of this set and possibly some other primitive domains like the domain of truth values or the domain of possible worlds. The simplest assumption on the structure of the $E$ domain is that it has no structure whatsoever: $E$ is assumed to be some arbitrary non-empty set.

In this sense, elements of $E$ are primitive or atomic – they are not defined in terms of other primitives in the theory. We assume that expressions like Prince Charles or Bill Clinton’s dog denote primitive members of the $E$ domain. Of course, this assumption abstracts over much knowledge that we as speakers may have about the internal structure of these entities. For instance, we may all know that Prince Charles has dark hair or that Bill Clinton’s dog has a brown ear. This however is not assumed to be part of the linguistic knowledge that model-theoretic semantics is supposed to describe.

Most semantic theories of plurals analyze sentences like Mary and John met or the students are a good team by introducing into the model a new notion of “plural entities”. These entities correspond to sets of atomic entities in the $E$ domain.\footnote{As will be mentioned below, in generalized quantifier theory this is not exactly so, since proper names denote generalized quantifiers and not members of $E$. This point is irrelevant for our present purposes.}

An alternative approach to collectivity, developed in Higginbotham and Schein (1989), Schein (1986) and Schein (1993), does not assume plural individuals but analyzes collectivity in terms of quantification over singular individuals using a particular version of event semantics (cf. Davidson (1967)). Sentences like the boys met are analyzed in this approach as resulting from universal quantification that can roughly be paraphrased by: there was a meeting event $e$ such that for every $x$, $x$ is a boy if and only if $x$ is an agent in $e$. The ontological implications of this view, as well as its implications for compositional semantics and the syntax/semantics interface, are interesting and worth extensive discussion, but go beyond the scope of this paper.

\footnote{I deliberately refrain from claiming that plural entities are sets, which is controversial. They do however correspond to sets under everyone’s assumptions.}
instance, the denotation of the plural noun phrase *Mary and John* is assumed to correspond to the set \{m', j'\}, consisting of the atomic entities denoting the proper name *Mary* and the proper name *John*. The denotation of a noun phrase like *the students* corresponds to the set \{s_1, s_2, ...\}, consisting of the singular entities denoting students in the model. This connection between atomic entities and "plural entities" makes linguistic sense because syntactically, plural NP coordinations like *Mary and John* are formed from singular NPs. Therefore, compositionally there must be a connection between the denotation of the complex plural noun phrase and the denotations of its lexical sub-constituents: the atomic denotations \(m'\) and \(j'\) of the singular conjuncts and the denotation of the coordinator *and*. Likewise, the denotation of the plural proper noun *students* should be derived from the denotation of the singular noun *student*, which ranges over atomic entities, and the denotation of the plurality morpheme.

The analysis of collectivity in simple sentences like the following is now extremely simple.

(7) Mary and John met.

We assume that the denotation \(\text{meet}'\) of the collective predicate *meet* ranges over plural entities. That is, it characterizes a set of plural entities. Sentence (7) is analyzed as asserting the following membership relation.

(8) \(\{m', j'\} \in \text{meet}'\)

In words: the plural entity consisting of the singular entities for *Mary* and *John* is in the set of entities that met. This simple analysis guarantees that sentence (7) is not treated as equivalent to the unacceptable sentence *Mary met and John met*, which is of course a minimal requirement from any theory of plurals. The reason no such equivalence is expected under the analysis in (8) is that semantic theory assumes no *a priori* relation between properties of a plural entity and properties of its atomic parts, just like it expects no semantic relation between the sentence *John is happy* and the bizarre sentence *John’s thumb is happy*.

In principle, sets of atomic entities in \(E\) that denote plural NPs can be unboundedly large. For instance, any number of singular proper names can be conjoined, so a conjunction *A and B and C and...* may need to correspond to any subset of the \(E\) domain containing the atomic entities for *A, B, C* etc. It is therefore natural to use the set of *all the non-empty subsets of \(E\)* as a new domain of plural entities. Let us denote this set by \(pl(E)\), which formally defined as follows.

\[
pl(E) = \wp(E) \setminus \{\emptyset\} = \{A \subseteq E : A \neq \emptyset\}
\]

The notation \(\wp(E)\) standardly stands for the power set of \(E\): the set of all subsets of \(E\) (including the empty set). The set \(pl(E)\) is this power set minus the empty set. Graphically, the move from \(E\) to \(pl(E)\) is illustrated in figure 1. The initial set \(E\) containing the atomic entities *a, b* and *c* is used as the basis for creating the set \(pl(E)\), which consists of the seven non-empty subsets of \(E\).

Note that under this definition, the singleton sets in the domain \(pl(E)\) directly correspond the \(E\) domain, as there is a one-to-one mapping between any singleton \(\{a\}\) in \(pl(E)\) and the element *a* of \(E\). Therefore, instead of using the domain \(E\), we can now use \(pl(E)\) as one unified domain of entities, where the distinction between
atomic and non-atomic entities is captured as a sort distinction between singleton sets and non-singleton sets. This is basically the move in most theories of plurals, including Scha (1981), Link (1983) and Landman (1989). Scha assumes a set theoretical domain like the one defined above. Link and Landman assume different algebraic structures. However, these three approaches are similar in assuming that denotations of singular NPs and denotations of plural NPs come from the same domain. The earlier work of Bennett (1974), however, uses both domains $E$ and $pl(E)$, assuming a type difference between singulars and plurals. Bennett’s approach will prove more useful for expressing the generalizations in the present paper.

2.2 Generalized quantifiers

The classical article by Barwise and Cooper (1981) assumes an $E$ domain of entities without any underlying structure. Consequently, Barwise and Cooper’s theory of generalized quantifiers is inherently “atomic”. The denotations of all intransitive predicates in Barwise and Cooper’s article are assumed to characterize subsets of $E$. All noun phrases in natural language are assumed to denote sets of such predicate denotations, or generalized quantifiers. In particular, Barwise and Cooper follow Montague (1973) and reverse the intuitive predicate-argument relation in simple intransitive sentences like the following.

(9) Mary smiled.

The traditional logical treatment of such simple sentences takes the NP to denote an element of the set characterized by the predicate denotation. This is formalized in (10a) below. Instead of this treatment, Montague and the generalized quantifier tradition take the denotation of the predicate to denote an element of the NP denotation, as illustrated in (10b).

(10) a. $m' \in \text{smile'}$
    b. $\text{smile'} \in \{A \subseteq E : m' \in A\}$

The trick in (10b) is in the assumption that a proper name like Mary, instead of denoting the the entity $m'$ itself, denotes the set of all predicates that hold of this entity. In other words, the proper name Mary denotes the set of all subsets of $E$ that contain $m'$. 

Figure 1: domains for plurality

Technion - Computer Science Department - Technical Report LCL9902 - 1999
It is easy to verify that the resulting assertion in (10b) is equivalent to the traditional analysis in (10a): the set of smilers is in the set of sets that include Mary if and only if Mary is in the set of smilers.

Noun phrases containing a determiner expression are analyzed as follows. The common noun (or complex N’ unit) is analyzed as a set, like intransitive predicates. The determiner is analyzed as a function from such sets to generalized quantifiers. For instance, both the singular use and the plural use of the determiner no in (12) below are analyzed as a function that maps any set $A$ (e.g. the denotation of the noun student/s in (12)) to the set of subsets of $E$ whose intersection with $A$ is empty. This definition of the denotation no’ is given in (11). Consequently, we get the analysis in (12a).

\[(11)\quad \text{no}'(A) = \{B \subseteq E : A \cap B = \emptyset\}\]

\[(12)\quad \text{No student/s smiled.}\]

\[\begin{align*}
a. \quad & \text{smile}' \in \text{no}'(\text{student}') \\
& \iff \text{smile}' \in \{B \subseteq E : \text{student}' \cap B = \emptyset\} \\
& \iff \text{student}' \cap \text{smile}' = \emptyset
\end{align*}\]

In words: the intersection of the set of students with the set of smilers is empty.

Moving on to another example of generalized quantifier theory, both the determiners every and all in (14) below are analyzed as denoting the function that maps any set $A$ to the set of sets that contain $A$. This is formally stated in (13). As a result, both sentences in (14) are correctly analyzed as asserting that the set of students is a subset of the set of smilers.

\[(13)\quad \text{every'}(A) = \text{all'}(A) = \{B \subseteq E : A \subseteq B\}\]

\[(14)\quad \text{Every student/all the students smiled.}\]

\[\begin{align*}
a. \quad & \text{smile}' \in \text{every'}(\text{student}') \iff \text{smile}' \in \text{all'}(\text{student}') \\
& \iff \text{smile}' \in \{B \subseteq E : \text{student}' \subseteq B\} \\
& \iff \text{student}' \subseteq \text{smile}'
\end{align*}\]

This sophisticated semantic analysis of NPs has many advantages. It allows a unified semantic treatment of many noun phrases, which is the basis for a simple analysis of “boolean” phenomena in natural language like coordination and negation, as well as of various semantic properties of NPs that affect their syntactic distribution.4

The atomicity of generalized quantifier theory in its Barwise and Cooper formulation makes it particularly suitable for modeling the semantics of singular NPs. Generalized quantifier theory in its standard version is also suitable for describing the semantics of plurals, but only as long as collectivity phenomena are not taken into account. We have seen that sentences like Mary and John met can be easily analyzed using the assumption about an entity domain with plural entities. However, to combine such a domain with atomicity the assumption of standard generalized quantifier theory is not a straightforward task. This project is nevertheless highly important for semantic theory, because, as the discussion in the introduction makes clear, collectivity appears

\[\text{\footnotesize 4For more details, see Barwise and Cooper (1981), and Keenan and Stavi (1986), or the more up-to-date surveys in Keenan (1996), Keenan and Westerståhl (1996) and van der Does and van Eijck (1996).}\]
also with semantically complex plural NPs like *no students* and *exactly five students*, and not only with "referential" NPs like *Mary and John* or *the students*. We may hope that the attractive uniformity of generalized quantifier theory will prove useful also in the study of such complex plurality phenomena. The following sections substantiate this hope.

3 Atom predicates vs. set predicates

Many theories of plurality distinguish predicates that range over atoms from predicates that range over sets of atoms. The traditional distinction between distributive predicates and collective predicates is often, more or less explicitly, assumed to be the criterion for an atom/set distinction between predicates. This section argues against this assumption. It is shown that it is hard to classify predicates as distributive or collective using robust intuitions about entailment between natural language sentences. Therefore, it is concluded that this distinction is not suitable for making a "rigid" model-theoretic distinction between predicates that range over atoms and predicates that range over sets. However, another typology of predicates is developed according to their truth-conditional behaviour with plural quantificational noun phrases. This new binary distinction between predicates is elegantly explained by the assumption that some predicates in natural language range over atoms whereas other predicates range over sets.

3.1 A former typology: distributive predicates vs. collective predicates

The traditional typology of natural language predicates according to their semantic number uses (implicitly or explicitly) equivalences/non-equivalences as in (15) below in order to classify predicates as distributive/collective.

\[
\begin{align*}
(15) \quad & \text{a. Mary and John smiled} \iff \text{Mary smiled and John smiled.} \\
& \text{b. Mary and John met} \not\iff \text{Mary met and John met.}
\end{align*}
\]

Thus, the defining criterion for whether a predicate \text{PRED} is distributive or collective is the following equivalence test (possible inflections on \text{PRED} are ignored).

\[
(16) \quad \text{Mary and John \text{PRED} } \iff \text{Mary \text{PRED} and John \text{PRED}.}
\]

Predicates like *smile*, *sleep* and *sneeze*, which satisfy this equivalence, are called *distributive*. Predicates like *meet*, *be a good team* and *live together*, which do not satisfy this equivalence are called *collective*.

Some of the predicates that are classified as collective according to this test are often assumed to be ambiguous or vague between a collective and a distributive interpretation, and they are referred to as *mixed predicates*. Consider for instance the predicate *drink a whole glass of beer*. This predicate certainly does not satisfy the equivalence in (16): sentence (17a) below can be true while sentence (17b) is false. This happens in situations where Mary and John drank a whole glass of beer between them, but neither of them drank a whole glass of beer on her own.

\[
(17) \quad \text{a. Mary and John drank a whole glass of beer.}
\]
b. Mary drank a whole glass of beer and John drank a whole glass of beer.

The reason predicates like *drink a whole glass of beer* are considered as different from predicates like *meet* is that the former but not the latter can easily be true of simple singular NPs like *Mary* or *the woman*. A second typological test that is therefore used (often implicitly) to determine the semantic number of a predicate PRED is according to its behaviour with such singular noun phrases, as in the following examples.

(18) Mary/John/the woman/the wall/the shop PRED.

Predicates like *meet*, which make sentences with all singular NPs as in (18) unacceptable, are referred to here using the label *completely collective (ccl)* predicates. Mixed predicates are those collective predicates that are not *ccl*.5

Many theories assume that the difference between distributive and collective predicates is that the former range unambiguously over atoms whereas the latter can range also over sets. Completely collective range only over sets, whereas mixed predicates range over both atoms and sets. As mentioned above, the domain $pl(E)$, containing both atomic entities (or their corresponding singletons as in figure 1) and plural entities, is assumed to be a uniform domain of entities for singular and plurals alike. Consequently, the distinctions between distributive, *ccl* and mixed predicates are assumed to reflect sort distinctions between the kinds of entities these predicates can hold of.

Summarizing, many theories of plurality make, either explicitly or implicitly, a three-way distinction among predicates according to their semantic number.

1. *Distributive* predicates like *sleep*, *smile* and *sneeze* hold of atoms in $pl(E)$.

2. *Collective* predicates are subdivided into:

   (a) *Completely collective (ccl)* predicates like *meet*, *be a good team* and *live together*, which hold of non-atomic elements of $pl(E)$.

   (b) *Mixed* predicates like *drink a whole glass of beer*, *lift a piano* and *weigh 140kg*, which hold of atomic and non-atomic elements of $pl(E)$.

To make sense of such typological tests as in (16) and (18) we have to verify that they generalize to more constructions than the ones given above. In this respect both tests we used (and any plausible alternative I know of) have to face some difficulties. The *ccl/non-ccl* test has to make explicit the kinds of NPs it allows to use as subjects in test sentences like (18). Simply taking these NPs to be the class of all morphologically singular NPs would remove much of the bite from this test. The reason is that singular "group referring" noun phrases like *the committee* or *the team* can appear as acceptable arguments of predicates normally classified as *ccl*. Consider for instance the following examples.

---

5The label "completely collective predicates" obviously presupposes that all these predicates are collective, but this natural assumption does not follow directly from the definitions given above. Suppose however that some predicate *blip* were *ccl* and distributive. By definition of *ccl* predicates, sentences like *Mary/John blip* would have been unacceptable, hence so would also (reasonably) be the conjunction *Mary blip and John blip*. By distributivity of *blip*, also the sentence *Mary and John blip* would have had to be unacceptable. Such a predicate like *blip* that is unacceptable with both singular NPs and their conjunctions would not be very useful in natural language. Thus it is indeed reasonable to assume that all *ccl* predicates are collective.
(19) The committee/team/class/group/senate meets/gathers on Tuesday.

Such acceptable sentences imply that the ccl/non-ccl typology can be linguistically defined only if there is a way to linguistically classify the class of “group referring” NPs, and to distinguish them from NPs like the woman. As previous works on this topic (e.g. Barker (1992), Landman (1989), Schwarzschild (1996: ch.9)) reveal, this is not a simple task. Moreover, it is not clear to me that even sentences like the woman met are unacceptable in all possible contexts. More concretely, as argued by Scha (1981) and Roberts (1987:124), such sentences exhibit similar incoherence to sentences that are commonly classified as violations of selectional restrictions. For instance, in a context like (20), the normally unacceptable sentence the woman met ameliorates, similarly to the sentence the idea fell asleep in context (21).

(20) ?I dreamt last night that women could be committees. In my dream I saw some woman who was a committee and then, suddenly, just before I woke up, the woman met.

(21) ?I dreamt last night that ideas could be bears. In my dream I had some idea that was a bear and then, suddenly, just before I woke up, the idea fell asleep.

What these points show is that it is hard to define the ccl/non-ccl classification as a general typological test for natural language predicates.

The same assertion holds also of the distributive/collective classification. It has been occasionally noted in the literature that many predicates that would intuitively be classified as distributive, do not in fact show the kind of entailments that distributive predicates are supposed to show. For instance, Dowty (1987) discusses the sentence in (22) and the discourse in (23).

(22) At the end of the press conference, the reporters asked the president questions.

(23) a. What was that noise?
    b. Oh, I’m sure it was only the children getting up to watch cartoons. Go back to sleep.

Sentence (22) does not assert that all the reporters asked questions. Similarly, sentence (23b) does not entail that all the children are getting up. Dowty (1987:103) concludes:

"I argue that even with 'true' distributive predicates, the question of how many members of the group referent of a definite NP must have the distributive property is in part lexically determined and in part determined by the context, and only rarely is every member required to have these properties."

Similar points are made in Scha (1981:141) and Landman (1996). This is a major problem for theories of plurality that take the notion of distributive predicates as a point of departure. Such theories naturally aim to account for equivalences like the following.

(24) Mary and John are getting up
    ⇔ Mary is getting up and John is getting up.
However, any theory known to me that is capable of accounting for such equivalence (e.g. the theory in Link (1983)) fails to account for the lack of equivalence Dowty observes between the following sentences.

(25) The children are getting up
$\not \Rightarrow$ Every child is getting up.

Conversely, a theory as in Scha (1981), which does not make any commitment to a distributive/collective between predicates, does not account for the (at least apparent) equivalence in (24).\(^6\)

Similar points lead Landman (1996,1997) to start questioning the generality of the distributivity equivalence in (16), even with with conjunctive NPs and typically "distributive" predicates like get up (cf. (24)), talk and smile. For instance, consider Landman’s (p.c.) example (26) and the similar example in (27).

(26) Groenendijk and Stokhof are talking at the conference.

(27) Simon and Garfunkel are singing in the Central Park.

For anyone who heard of the semantic couple G&S it may well occur that (26) can be true without both semanticists having to talk at the conference. In fact, Landman points out that (27) may be true even if only Stokhof is giving a joint talk by G&S while Groenendijk did not even arrive at the conference (or the other way around). Similarly, for anyone who heard of the musical couple S&G, sentence (27) may be true without both musicians singing. The sentence can be true, for instance, where only Garfunkel is singing while Simon is playing the guitar mouth closed. These points hold despite the fact that under more generic names (e.g. the occasional Mary and John), parallel equivalences do seem to hold with the predicates sing and talk. These are some of the "recalcitrant and 'fuzzy' data surrounding the collective/distributive distinction" referred to by Dowty (1987:97), which make it hard to use this distinction as a general criterion for the classification of predicates.

The conclusion from this negative claim is not necessarily discouraging. All we have seen is that it is hard to find a robust criterion that distinguishes between the classes of distributive, collective and mixed predicates. It is therefore reasonable that the distinctions between predicates that these traditional terms refer to are to be explained using "soft" lexical semantic notions like selectional restrictions, rather than by "rigid" model-theoretic distinctions like the distinction between predicates ranging over atoms and predicates ranging over sets. The notoriously elusive selectional properties of predicates in natural language will not be studied here. On the other hand, assuming that the distributive/collective typology does not motivate a model-theoretic distinction between predicates according to their semantic number, the remaining question is whether there are any other linguistic phenomena that do motivate such a difference. The next subsection answers this question affirmatively: there is a truth-conditional criterion, closely related to the distributive/collective distinction, which provides evidence for an atom/set distinction between predicates.

\(^6\)See Lasersohn (1990:10-11) for relevant discussion.
3.2 A new typology

One of Dowty’s central observations is that predicates like be a good team differ from predicates like meet in disallowing collective interpretations of NPs headed by all.\(^7\) Dowty observes that sentence (28a) below is coherent and meaningful, whereas sentence (28b) is unacceptable.

\[(28) \begin{align*}
\text{a. All the students met.} \\
\text{b. *All the students are a good team.}
\end{align*}\]

In this respect a plural noun phrase like all the students sharply contrasts with a singular noun phrase like every student, which is unacceptable with both kinds of predicates, as the sentences below illustrate.

\[(29) \begin{align*}
\text{a. *Every student met.} \\
\text{b. *Every student is a good team.}
\end{align*}\]

In other words we may therefore describe the contrast between the predicate meet and the predicate be a good team by saying that while the former predicate is sensitive to the replacement of all by every, the latter is not: it is unacceptable in both cases.

The same distinction between predicates can be made using other pairs of plural/singular words besides all and every. For instance, the contrast between the predicate meet and the predicate be a good team is preserved when all is replaced the determiner no in its plural use and every is replaced by singular no. Likewise, we can use the plural/singular pairs of determiners at least two/more than one or many/many a, and observe a similar contrast between the two predicates. This is illustrated in the following examples.

\[(30) \begin{align*}
\text{No} & \quad \{ \text{At least two} \} \quad \text{students} \quad \{ \text{met} \} \\
\text{Many} & \quad \{ \text{are a good team} \}
\end{align*}\]

\[(31) \begin{align*}
\text{No} & \quad \{ \text{More than one} \} \quad \text{student} \quad \{ \text{met} \} \\
\text{Many a} & \quad \{ \text{is a good team} \}
\end{align*}\]

Thus, we see that the contrast Dowty observed between the predicates meet and be a good team is unlikely to appear only as a result of the semantics of all.\(^8\) It is a systematic difference between the behaviour of these predicates with more morphologically

\(^7\)Like Dowty, I ignore throughout this paper the interesting but subtle differences between noun phrases like all the students, noun phrases like all students and cases of floating all, as in the students all smiled.

\(^8\)This assumption implicitly underlies Dowty’s analysis. Dowty suggests an informal notion of “sub-entailments” of a predicate, and analyzes a sentence like all the students met as “the students met and every student satisfies a sub-entailment of meet”, where meet sub-entails some contribution to a meeting. Whatever the definition of sub-entailments may be, it is clear that this line of analysis would not work for sentences like no students met, which would paradoxically be analyzed as stating “the students met and no student contributed to any meeting”. Similar problems appear for the proposals in Taub (1989) and Brisson (1997). Like Dowty, also Brisson and Taub concentrate on all and ignore other plural determiners that behave the same with respect to the distinction under discussion between predicates.
plural noun phrases, compared to their behaviour with corresponding singular NPs. The crucial point is that now, instead of concentrating on “referential” noun phrases like *Mary and John* and *the students* as in the distributive/collective classification of the former subsection, we turn our attention to the behaviour of predicates with “quantificational” NPs. In general, we classify a predicate *PRED* according to its behaviour in sentences like the following.

\[(32) \quad \text{a. all the/no/at least two/many students } PRED \]
\[\quad \text{b. every/no/more than one/many a student } PRED \]

To have names for the two kinds of predicates we recognized, let us introduce the following terminology.

**Terminology:** Let *PRED* be a natural language predicate (verb, noun or adjective). Assume the sentences in (32a) and the corresponding sentences in (32b) are equally acceptable and, if acceptable, are furthermore semantically equivalent. Then *PRED* is called an atom predicate. If the respective sentences in (32a) and (32b) differ in either acceptability or truth-conditions then *PRED* is called a set predicate.\(^9\)

Although both predicates *meet* and *be a good team* are traditionally classified as collective predicates, according to the above criterion the predicate *meet* is classified as a set predicate whereas *be a good team* is called an atom predicate. The theoretical reason for this choice of terminology is that this is the proposed criterion for defining which predicates range over atoms and which ones range over sets. Let us however use these terms for the time being as purely descriptive terms for the two kinds of predicates we have identified.

Note that what matters for the atom/set criterion is not simply acceptability/non-acceptability judgements, but also truth-conditions. For instance, the predicate *meet* qualifies as a set predicate because it is sensitive to the replacement of *every* by *all*, singular *no* by plural *no*, and so on. This sensitivity may surface as a difference in acceptability as between the pairs (28a)/(29a) or the *meet* pairs in (30)/(31) above. However, the sensitivity of the predicate *meet* to morphological number of the determiner appears also as a truth-conditional distinction between pairs of sentences that are both acceptable. For instance, consider the following sentences.

\[(33) \quad \text{a. All the committees met.} \]
\[\quad \text{b. Every committee met.} \]

In this case both sentences (33a) and (33b) are acceptable, but yet they are not equivalent: while (33b) unambiguously reports on meetings of *individual* committees, sentence (33a) may be interpreted as reporting on a joint meeting of the committees *together*, with no respect to individual meetings each committee might have had. This judgement is quite robust for the speakers I consulted. I propose that the origin for the meaning difference in (33) is strongly connected to the acceptability differences we have observed above, where the noun *students(s)* is used instead of *committee(s)*.

Let us give a brief typological survey of atom predicates and set predicates according to the above criterion. Some more *ccl* predicates like *be a good team* that

---

\(^9\)For nouns or adjectives substituted for *PRED*, we may need (in some languages, like English) to add a *be* verb in front of the predicate in (32), in case it is a singular noun, also an indefinite article.
are classified as atom predicates are *be numerous, form a pyramid* and *elect the representative*. This is shown by the similar status of the sentences in the following *a/b* pairs.

(34) a. *All the/no/etc. students are numerous/formed a pyramid/elected the representative.*
    b. *Every/no/etc. student is numerous/formed a pyramid/elected the representative.*

Atom predicates also clearly include distributive predicates like *smile* or *sleep*, as the equivalences below show.

(35) Every/no/etc. student smiled/slept
    ⇔ All the/no/etc. student smiled/slept.

A further interesting fact pointed out by Dowty (attributing it to Bill Ladusaw) concerns the sentences in (36) below.

(36) a. The students voted to accept the proposal.
    b. Every student voted to accept the proposal.
    c. All the students voted to accept the proposal.

The predicate *vote* leads to a collectivity effect with plural definite subjects as in sentence (36a), where the reported vote need not be unanimous. That is, sentence (36a) is not equivalent to (36b). This non-equivalence, plus the acceptability of sentences like *Mary voted to accept the proposal*, classifies *vote* as a mixed predicate on its subject argument. On the other hand, Dowty and Ladusaw observe that sentence (36c), with an *all* noun phrase, is equivalent to (36b). This clearly characterizes *vote* as an atom predicate. I think that a similar effect appears also in (37) below with the verb *weigh*.

(37) a. The potatoes in this basket weigh 1kg.
    b. Every potato in this basket weighs 1kg.
    c. All the potatoes in this basket weigh 1kg.

This shows that not only completely collective predicates (e.g. *be a good team*) or distributive predicates (e.g. *smile*) are atom predicates. Also mixed predicates like *vote* or *weigh* are.

*Set predicates*, in addition to the predicate *meet*, also include *cel* predicates like *gather* and *be similar*, as well as reciprocated predicates like *admire each other*. This is demonstrated by difference in acceptability between the following pairs.

(38) a. *Every/no/etc. student gathered/is similar/admired each other.*
    b. All the/no/etc. students gathered/are similar/admired each other.

With many “mixed” predicates like *lift a piano* there is probably some variation among speakers. For instance, Dowty (1987:104) recognizes a “collective interpretation” of sentence (39a), which means he reads it as non-equivalent to (39b).

(39) a. All the students in my class performed Hamlet.
b. Every student in my class performed Hamlet.

Thus, in Dowty’s dialect the predicate perform Hamlet – and presumably other mixed predicates like lift a piano – is a set predicate. For convenience, I henceforth refer to this (possible) English dialect as Dowty’s dialect. Dowty mentions that some people find collective interpretations in (39a) more natural if the word together is added. This seems to be correct also for speakers like Dowty who do not take (39a) and (39b) to be equivalent. Other speakers, however, are stricter and consider (39a) and (39b) to be totally equivalent. For these speakers, only when together is added can the sentences become non-equivalent. Using the present terminology, in this dialect, unlike in Dowty’s dialect, the predicate perform Hamlet is an atom predicate and only the word together can modify it into a set predicate. A similar point holds for many other “mixed” predicates like drink a whole glass of beer, lift a piano or write a book.

Moving on to the nominal domain, it is important to note that the criterion we use classifies predicates as atom or set independently of their morphological number. Thus, plural forms of nominals, verbs and adjectives (in languages where adjectives have number inflection) get the same classification as their singular forms. For instance, both the singular noun student and its plural form students are classified as atom predicates due to the equivalence in (40) below. Relational nouns like colleagues, sisters, friends and so on qualify as set predicates according to non-equivalences as in (41a). Another way to obtain a (complex) set nominal is to modify an atom nominal by a set predicate as illustrated in (41b-c).

(40) Every woman is a student
⇔ All the women are students.

(41) a. ?Every woman is a colleague/sister/friend
    ¬ All the women are colleagues/sisters/friends.

b. ?Every woman is a similar student
    ¬ All the women are similar students.

c. *Every woman is a student who met yesterday at school
    ¬ All the women are students who met yesterday at school.

To end the discussion of nominals, consider “group denoting” nouns like team, as in the predicate nominal in the following equivalence.

(42) Every group of tall people is a good basketball team
⇔ All groups of tall people are good basketball teams.

This kind of equivalence shows again that predicates like be a good basketball team should belong to the class of atom predicates like be a good law student or sleep, despite the (arguably misleading) impression that nouns like team and group semantically differ in their “semantic number” from nouns like student.10

The following list gives a summary of atom predicates and set predicates according to the criterion we defined above.

(43) Atom predicates:

10 This assumption is crucial for the proposals in Barker (1992), Schwarzschild (1996) and Winter (1998b:ch.5), which all treat such “group referring” nouns as ranging over atoms.
a. sleep, smile, get up
b. be a good team, be numerous, form a pyramid, elect Clinton, constitute a majority, outnumber (both arguments), be alone
c. vote to accept the proposal, weigh 1kg
d. (in some dialects:) perform Hamlet, lift a piano, write a book
e. student(s), child(ren), shop(s), team(s), committee(s)

(44) Set predicates:

a. meet, gather, disperse
b. be similar, be alike, be together
c. like each other, look at one another
d. perform Hamlet together, lift a piano together, write a book together
e. (in Dowty’s dialect:) perform Hamlet, lift a piano, write a book
f. colleague(s), brother(s), friend(s), similar student(s), student(s) who met

Note the differences and the similarities between the atom/set distinction and the traditional distributive/collective typology. An atom predicate can be distributive (e.g. sleep), completely collective (e.g. be a good team) or mixed (e.g. vote). All set predicates in Dowty’s dialect are collective (mixed or completely collective). In other dialects all set predicates are completely collective. Logically, in both kinds of dialects all distributive predicates are atom predicates. This situation is graphically illustrated in figure 2.

Figure 2: typologies of predicates

What in my view is especially attractive in the new atom/set typology is its robustness. The test used to distinguish atom predicates from set predicates is stated in terms of entailment between natural language sentences. These entailments are argued to hold independently of context, of use or lexical choice of other elements in the sentence besides the relevant predicate and determiner. If this claim is correct, then
the atom/set typology, and not the traditional distributive/collective classification, is a natural criterion for making a "rigid" model-theoretic distinction between denotations of predicates according to their semantic number. This distinction is proposed as a general principle of the lexical semantics of predicates.

**Principle 1** Denotations of lexical atom predicates range over **atoms** (=elements of \( E \)). Denotations of lexical set predicates range over **sets of atoms** (=elements of \( \mathcal{P}(E) \)).

The terms "atom predicates" and "set predicates", which classify the linguistic behaviour of predicates pre-theoretically only, were of course chosen with this theoretical hypothesis in mind. Intuitively, it is quite clear that the model-theoretic distinction just made between atom predicates and set predicates can be used to explain their different behaviour. Set predicates lead to collectivity with plural noun phrases like *all the students or no students* because the denotations of these plural NPs range over sets, as will be proposed below. With singular NPs like *every student or no student*, whose denotations are assumed to range over atoms, no collectivity effect can appear. Atom predicates, by contrast, do not show collectivity even with the mentioned plural NPs. This is simply explained because the denotation of atom predicates does not encode any information about sets.

These preliminary ideas are of course in need of elaboration. First, we need to clarify the exact difference in denotation between singulars and plurals. Second, we now lack an understanding of why atom predicates do nevertheless show collectivity with certain plural noun phrases: "referential" NPs like *Mary and John* and *the students*. These two questions are addressed in the following two sections.

### 4 Singular predicates vs. plural predicates

The effects of morphological number marking on the availability of collective interpretations can be illustrated using the contrasts between the sentences in (45) and the sentences in (46), reproduced from the above examples.

\[
\begin{align*}
(45) \quad \left\{ \begin{array}{l}
\text{All the} \\
\text{No} \\
\text{At least two} \\
\text{Many}
\end{array} \right\} \text{ students met.}
\end{align*}
\]

\[
\begin{align*}
(46) \quad * \left\{ \begin{array}{l}
\text{Every} \\
\text{No} \\
\text{More than one} \\
\text{Many a}
\end{array} \right\} \text{ student met.}
\end{align*}
\]

The reason for the focus on *lexical* atom and set predicates will become clear in the next subsection.

In cases of predicates with more than one argument, principle 1 relates to each argument separately, though formal details are obviously missing. For instance, we have seen above that the transitive predicate *elect* is atomic on its subject argument, hence this argument is assumed to be an element of \( E \). Whether a predicate is an atom predicate or a set predicate on its *object* argument should be tested independently. For instance, the predicate *see* should be classified as atomic on its object argument due to equivalences as between the sentences *John saw every student* and *John saw all the students*. However, further discussion of this point must be deferred to another occasion.
In standard generalized quantifier theory, pairs of determiners like every and all, singular no and plural no, or more than one and at least two are treated as synonyms. However, contrasts like the ones between (45) and (46) show that something more has to be said about the reasons why collective quantification in natural language is possible with count NPs in the plural but not with count NPs in the singular. In the systems of Scha (1981) and Van der Does (1992,1993), which are presumably the most elaborated treatments of plurals in generalized quantifier theory, it is implicitly assumed that plural determiners can range over sets, while singular determiners cannot. However, this assumption comes only by means of lexical or syntactic stipulations on particular lexical items. No generalization concerning the relationships between morphological number and semantic number appears explicitly in the Scha and Van der Does systems. Scha, for instance, assigns all, in addition to a distributive reading à la Barwise and Cooper, also a collective reading. The determiner every has only one reading, identical to the distributive reading of all. Similar stipulations have to be duplicated for all singular and plural determiners. Van der Does uses general type lifting operators from standard determiners over atoms to determiners over sets. To rule out collective lifts with singular determiners like every, Van der Does uses a syntactic feature that is stipulated for determiners classified as “intrinsically distributive”. However, no general principle in the system guarantees that these determiners are in the singular.

The present proposal, which is similar in some respects to Van der Does’ lifting strategy (as will be clarified below), differs from both Scha and Van der Does’ systems in taking the noun to be the center of the atom/set distinction within the noun phrase. I propose that singular nouns, as well as all other singular intransitive predicates (i.e. verbs and adjectives in the singular), unambiguously range over atoms. Plural nouns, like all other plural one-place predicates, range over sets. The set denotation of plural predicates is claimed to be the main source of collectivity effects with plurals. On the other hand, the denotation of natural language determiners is insensitive to their singular/plural number feature and they all invariably range over atoms as in standard generalized quantifier theory.

The immediate question that arises is of course how sentences with plural determiners can ever end up having collective interpretations. My answer is based on the

---

12It should be noted that non-collectivity with singular count NPs is not a universal phenomenon despite its robustness in English and many other languages. Agnes Bende-Farkas and Anna Szabolcsi point out that Hungarian allows collectivity with some singular count NPs. For instance:

(i) Minden/ az összes/ a legtöbb/ sokdi ak össze-gyült
Every/ the all/ the most/ many student together-gathered
"All the/all the/most of the/many students gathered"

The study of such phenomena is left for further research.

13Both Scha and Van der Does define the denotations of all determiners as functions from noun denotations ranging over atoms to quantifiers ranging over sets (in Van der Does’ system, these functions are lifted denotations of standard determiners that range over atoms). Thus, there is no distinction in these systems between singular and plural: all nouns range over atoms and all determiners map them to quantifiers ranging over sets.

14Cross-linguistically, this uniformity is not less plausible than the alternative idea of distinguishing between meanings of plural determiners and singular determiners. Many languages use the same morphology for singular determiners and their plural correlates. Consider for instance the singular/plural English determiner no (as in no student!), or the singular/plural Hebrew determiner kol ("each/’all”). In such cases it is natural to assume that both items are just one and the same morpheme, unspecified for the number feature, in a similar way to words like the English nouns fish and sheep.
possible type mismatch between the determiner, ranging over atomic elements from $E$, and the plural noun, which ranges over sets from $pl(E)$. Following Partee and Rooth (1983), such mismatches, and only such mismatches, trigger the application of type shifting principles. These are operations that change the type of an expression when it does not fit its semantic environment. In the case under discussion, a type shifting operator changes the denotation of the determiner to range over sets when its semantic composition with the noun denotation fails because the latter ranges over sets. Once its type has changed, the determiner denotation can compose with the plural noun denotation so that the noun phrase finally denotes a quantifier over sets. This quantifier can successfully compose with the main set predicate in the sentence. This is how sentences as in (45) (e.g. all the students met) are interpreted. Note however, that this whole process is only triggered by the plurality of the noun, which allows its denotation to range over sets. When the noun is in the singular as in (46) (e.g. *every student met), it unambiguously ranges over atoms and does not trigger any change in the type of the determiner. Consequently, quantification with singular NPs remains unambiguously "distributive".

Let us officially summarize the proposal above as the following general principle.

**Principle 2**

(a) Denotations of singular predicates range over atoms.\(^{15}\) Denotations of plural predicates range over sets of atoms. (b) Type mismatches between denotations ranging over atoms and denotations ranging over sets are resolved using type shifting principles.

How do principle 1 and principle 2 interact? That is, how do the atom/set classification of the predicate and its singular/plural morphological number together determine whether its denotation derives collective readings or not? The key to answering this question is our assumption in principle 1 that the descriptive atom/set classification affects only the lexical denotation of the predicate. However, what determines the denotation of the number inflected predicate is also its number morphology (singular or plural) as stated in principle 2. What this principle actually makes sure is that singular and plural number features have a meaning that can override the lexical consequences of the atom/set classification of predicates: the singular number feature coerces the denotation of a predicate to range over atoms, even if it is a set predicate; likewise, the plural number feature allows the denotation of a predicate to range over sets, even if it is an atom predicate.

Of course, we need to define how precisely meanings of number inflected predicates are derived from their lexical meanings. For instance, it is assumed that predicates in the plural range over sets. Therefore, some operator should intermediate

\(^{15}\)This is not necessarily true for English mass nominals. For instance, while the count nominal piece of sugar in (i-a) below distinctly differs from its plural counterparts in (i-b), the mass noun sugar does show collectivity in (ii).

(i)  
   a. All the pieces of sugar are concentrated in this container.  
   b. *Every piece of sugar is concentrated in this container.

(ii) All the sugar is concentrated in this container.

I believe that the recent analysis of mass terms in Chierchia (1998) can be combined with the present proposal to account for such puzzles, and perhaps also for the collective behaviour of Hungarian count nouns mentioned in footnote 12.
between the lexical denotation of atom predicates and the set denotation of their plural form. In a similar way, another operator should connect the lexical denotation of set predicates to the denotation of their singular form. As for the first case, let \( X \subseteq E \) be the lexical denotation of an atom predicate. In the plural form of the predicate, this set of atoms is mapped to a set of sets. This is achieved using the \( pl \) operator, whose definition is restated below.

\[
pl(X) = \{ A \subseteq X : A \neq \emptyset \}
\]

In words: \( pl \) maps \( X \) to the set of all its non-empty subsets.

Moving on to set predicates, let \( X' \subseteq pl(E) \) be a set of sets that a lexical set predicate characterizes. In the singular form of the predicate, this set of sets is mapped to a set of atoms. This is achieved using an inverse operator to the \( pl \) operator, which we denote by \( sg \). Formally this inverse operator is defined as follows.

\[
sg(X') = \{ x \in E : \{ x \} \in X' \}
\]

In words: \( sg \) maps \( X' \) to the set of atoms \( x \) that constitute singletons \( \{ x \} \) in \( X' \).

Let us summarize the way these operators are used in deriving the denotation of singular and plural atom predicates and set predicates.

1. Let \( X \subseteq E \) be the lexical denotation of an atom predicate \( \text{PRED}_a \).
   
   (a) The denotation of the singular form of \( \text{PRED}_a \) is naturally \( X \) itself.
   
   (b) The denotation of the plural form of \( \text{PRED}_a \) is \( pl(X) \).

2. Let \( X' \subseteq pl(E) \) be the lexical denotation of a set predicate \( \text{PRED}_s \).
   
   (a) The denotation of the singular form of \( \text{PRED}_s \) is \( sg(X') \).
   
   (b) The denotation of the plural form of \( \text{PRED}_s \) is naturally \( X' \) itself.

Now we can use this abstract discussion to analyze four examples adapted from the preceding empirical survey.

(47)   a. *Every student elects Clinton.
   
   b. *All the students elect Clinton.
   
   c. *Every student meets.
   
   d. All the students meet.

The noun \( \text{student(s)} \) and the verb phrase \( elect(s) \text{ Clinton} \) are classified as atom predicates. Hence, the lexical denotations \( \text{student}' \) and \( elect \text{_C}' \) are subsets of \( E \).\(^{16}\) The predicate \( meet \) is a set predicate and its lexical meaning is therefore a subset of \( pl(E) \).

\(^{16}\)I simplify things and incorrectly assume that \( elect \text{ Clinton} \) is a lexical predicate. However, the classification of this complex predicate as an atom predicate is solely affected by the atom status of the subject argument of the \( \text{lexical} \) transitive verb \( elect \).
According to the above assumptions, the denotations of the number inflected predicates are as follows.\(^{17}\)

<table>
<thead>
<tr>
<th>Student</th>
<th>Inflected Predicate</th>
<th>Inflected Predicate (plural)</th>
</tr>
</thead>
<tbody>
<tr>
<td>student</td>
<td>elect(_C^i)</td>
<td>pl(\langle\text{student}\rangle)</td>
</tr>
<tr>
<td>elects Clinton</td>
<td>pl(\langle\text{student}\rangle)</td>
<td></td>
</tr>
<tr>
<td>meets</td>
<td>sg(\langle\text{meets}\rangle)</td>
<td></td>
</tr>
</tbody>
</table>

The determiners *every* and *all* are assumed to be synonyms as in standard generalized quantifier theory (cf. subsection 2.2). The lexical meanings *every\(^i\)* and *all\(^i\)* of these determiners are equal, and both express the subset relation between sets of atoms, as defined in (13). By our assumptions so far, the meanings of sentences (47a-d) are respectively analyzed as follows.

\[
\begin{align*}
\text{(48)} & \quad \text{a. } \text{elect}_\text{C}^i \in \text{every}^i(\text{student}^i) \\
& \quad \text{b. } \text{pl}(\text{elect}_\text{C}^i) \in \text{all}^i(\text{pl}(\text{student}^i)) \quad \text{(type mismatch)} \\
& \quad \text{c. } \text{sg}(\text{meets}^i) \in \text{every}^i(\text{student}^i) \\
& \quad \text{d. } \text{meets}^i \in \text{all}^i(\text{pl}(\text{student}^i)) \quad \text{(type mismatch)}
\end{align*}
\]

The meanings in (48a) and (48c) are well defined. Those in (48b) and (48d) are not, due to the type mismatch between the determiner *all*, whose denotation *all\(^i\)* (=*every\(^i\)*) ranges over atoms, and the noun *students* whose denotation *pl\(\langle\text{student}\rangle\)* ranges over sets. Let us start by discussing the first two cases. In (48a), sentence (47a) is simply analyzed as claiming that the set of atomic student entities is a subset of the set of atomic entities that elected Clinton. This claim does not normally make sense, as no individual student (at least not in normal situations) can determine on his own the results of the elections.\(^{18}\) I argue that this is the source of the unacceptability of (47a), which is similar in its status to sentences like *every car contemplated*. In (48c), the predicate *meets*, because of its singularity, is analyzed as the set of atoms *sg\(\langle\text{meets}\rangle\)*: the atoms *x* whose corresponding singleton \{x\} is in the denotation of *meet*. Such an atom can be for instance a committee (cf. *the committee meets*), but normally not a student, once more due to the selectional restrictions of the predicate. We see again that the unacceptability of sentences like (47a) and (47c) is not analyzed as a grammatical matter, at least not the part of grammar addressed in this paper. The grammatical distinctions between atom/set predicates and singular/plural morphology only determine the truth-conditions of such sentences, which are themselves unacceptable due to selectional restrictions.

Moving on to sentences (47b) and (47d), the type mismatch in the analyses (48b) and (48d) is to be resolved using the type shifting operator that shifts the meaning of determiners to range over sets instead of atoms. Let us denote this operator by the symbol *dfit*, for *determiner fitting*. The type mismatches in the analyses (48b) and (48d) are resolved by applying *dfit* to the denotation of *all* as follows.

\[
\begin{align*}
\text{(49)} & \quad \text{b. } \text{pl}(\text{elect}_\text{C}^i) \in \text{dfit}(\text{all}^i)(\text{pl}(\text{student}^i))
\end{align*}
\]

\(^{17}\)I assume that the forms *elect Clinton* and *meet* are of verbs in sentences with a third person subject, so they are assumed to be plural. In their singular use (e.g. with the subject *I*), these forms are treated just like the singular third person forms *elects Clinton* and *meets*.

\(^{18}\)As in the case of other *ccl* predicates, there are singular NPs (e.g. *the American nation*) that can appear felicitoiusly as arguments of the predicate *elect Clinton*. Under the analysis here, this implies that there are atomic entities, though not singular students, that are plausible in the extension of this predicate.
In order to see the implications of this type change for the analysis of sentences (47b) and (47d) we have of course to define the $dfit$ operator. As this definition requires some subtle formal semantic technicalities, I introduce it only in appendix A. However, let us already mention its main implications for the analysis of the above sentences. In (49b), the application of the $dfit$ operator and the two applications of the $pl$ operators have a neutralizing effect on each other. Consequently, the analysis in (49b) of sentence (47b) turns out to be equivalent to the analysis of sentence (47a) in (48a). Thus, the unacceptability of these two sentences is accounted for along the same lines. By contrast, in (49d) the denotation $meet'$ intrinsically ranges over sets: unlike the situation in (49b), this is a lexical denotation of a set predicate rather than a lifted atom predicate. In such cases the $dfit$ operator has a significant semantic effect, which results in the collective interpretation of sentence (47d). More details on the formal reasons this is so will be given in appendix A.

Before concluding this section, let me just introduce a subtle detail that was ignored in the discussion above for the sake of exposition. As we saw above, quantification with plurals as in sentence (33a) (=all the committees met) is ambiguous between a distributive reading and a collective reading. I propose that the reason for this ambiguity is the lexical ambiguity of the plural feature on English predicates. On one reading, plurality forces the predicate to range over sets. On another reading, plural predicates are just equivalent to their singular form and range over atoms. An illustration of this assumed ambiguity is given in the two possible analyses of sentence (50) below.

(50) All the committees met.

a. $all'(committee')(sg(mee't'))$

b. $dfit(all')(pl(committee')(mee't'))$

In the analysis (50a), the common noun committees gets its lexical denotation, ranging over atoms. Consequently, no type mismatch with $all$ occurs and the subject ends up denoting a quantifier over atoms. Therefore also the predicate meet must get its atomic denotation using the $sg$ operator. The resulting reading is equivalent to the sentence every committee met. Under the analysis in (50b), the plurality of the common noun committees allows it to range over sets using the $pl$ operator. As a result, a type mismatch with $all$ occurs, which is resolved using the $dfit$ operator, which derives the collective reading (see appendix A).

Once we add the assumption about the ambiguity of plural predicates to the above mechanism, predicates get the denotations described in table 1. In this table $X$ is the lexical denotation of an atom predicate and $X'$ is a lexical denotation of a set predicate.

---

19 A similar point is made in Heim et al. (1991:78) concerning plural pronouns: "They or themselves here are singular variables whose values are (atomic) individuals; nevertheless, they are morphologically plural, even obligatorily so." In a similar way, I assume that predicates can optionally range over atomic entities also when they are morphologically plural.
5 Quantificational NPs vs. non-quantificational NPs

So far, we have concentrated on collectivity effects of various predicates with noun phrases like *all the students* and *no students*. We saw that set predicates show collectivity effects with such NPs, whereas atom predicates do not. This is exemplified below once more using our two prototypical examples for atom predicates and set predicates, but this time with a larger class of noun phrases.

\[
\begin{array}{c|c|c}
\text{atom} & \text{singular} & \text{plural} \\
\hline
\text{set} & X & \{ pl(X), X \} \\
\end{array}
\]

\[X \subseteq E, \quad X \subseteq pl(E)\]

Table 1: predicate denotations

However, with many other NPs the contrast between atom predicates and set predicates vanishes. Consider for instance the following sentences.

\[
(51) \begin{cases}
\text{all the} \\
\text{exactly four} \\
\text{between four and ten} \\
\text{more/less than eleven} \\
\text{at least/most twelve} \\
\text{few/many} \\
\text{no} \\
\text{most of the/?most}
\end{cases}
\]

\[
\text{students} \begin{cases}
\text{met} \\\n\text{are a good team}
\end{cases}
\]

\[
(52) \begin{cases}
\text{the students} \\
\text{some students I know} \\
\text{five students I know} \\
\text{Mary and John} \\
\text{a/some student and a/some teacher I know} \\
\text{the student(s) and the teacher(s)}
\end{cases}
\]

\[
\text{met} \begin{cases}
\text{are a good team}
\end{cases}
\]

Such collectivity effects with atom predicates like *be a good team* are not explained by the two hypotheses above. To complete our classification of "collectivity triggers" we should therefore account for these effects and for the origins of the contrast they show between the NPs in (52) and the NPs in (51).

Surprisingly, a division between NPs along the lines that the contrast between (51) and (52) shows is often assumed in linguistics and philosophy of language for quite different motivations. Noun phrases like the ones in (51) are occasionally labeled *quantificational NPs*, whereas NPs as in (52) are sometimes called *referential*.

\footnote{With the indefinite subjects in (51) and the "individual level" predicate *be a good team*, some speakers get acceptable generic readings. For instance, the sentence *exactly four students are a good team* may be read as *to be exactly four students is to be a good team*. However, any coherent reading besides this generic reading is strictly impossible. To support this claim, replace the predicate by a "stage level" predicate like *are the team that won the cup yesterday*, which does not give rise to generic readings. This makes the sentence completely uninterpretable.}
These names suggest that referential NPs make direct reference to entities (singular or plural), whereas the relation of quantificational NPs to entities is more indirect. The meaning of such NPs is assumed to involve quantifiers as in the predicate calculus or generalized quantifier theory. In this distinction between referential NPs and quantificational NPs, indefinites have an especially controversial status. Many works follow the tradition of Russell (1919) and argue that indefinites must be treated as quantificational. Some other works however agree with the logical tradition of Hilbert and Bernays (1939) and stress the similarity between indefinites and definite NPs. Notably, Fodor and Sag (1982) use the special scope properties of indefinites (see below) to argue that indefinites like some student I know must be able to make direct reference to entities. Similar arguments have been also made in the literature concerning the plural indefinites in (52).

Let us accept for the time being these informal intuitions about the "referential" status of the NPs in (52), and relate them to previous work on plurals in a way that will lead us to an account of the contrast between (51) and (52). Link (1983), and more extensively Landman (1989,1996,1997), argue for a semantic analysis in which plural entities (e.g. sets) are mapped to atomic entities. Link refers to such atoms that are derived from sets as impure atoms. Consider for instance the "referential" noun phrase the students in (52). Assume further that the students under discussion constitute the basketball team of their school. According to the Landman/Link proposal, the set corresponding to the noun phrase the students can be mapped in the semantic analysis to the atom denoting the noun phrase the school’s basketball team. Using this mapping, the sentence the students are a good team is interpreted as equivalent to the sentence the school’s basketball team is a good team. This last sentence is of course perfectly acceptable, and hence also the acceptability of the former sentence is expected. By contrast, consider now an unacceptable sentence from (51) like all the students are a good team. In this case we have a quantificational NP, which cannot be mapped to an impure atom. Therefore, all we have said in the preceding subsections about the analysis of this sentence’s unacceptability is still valid: due to the atomic status of the predicate, the sentence is still analyzed as equivalent to the unacceptable sentence every student is a good team.

The mapping of sets to atoms as discussed above is proposed here as the general reason for collectivity and non-distributivity effects with atom predicates, not only ccl predicates like be a good team. Consider for instance examples like the following ones, reproduced from section 3 above.

(53) The children are getting up. (cf. (23))

(54) Groenendijk and Stokhof are talking at the conference. (= (26))

In Dowty’s example (53), the context in (23) makes clear that the children under discussion constitute a unity, which is “collectively” disturbing the silence in the house. In Landman’s example (54), it is clear to any speaker who gets the collectivity effect that Groenendijk and Stokhof are conceived here as one team. Like Landman (1996) (and in another context, Verkuyl (1994)), I propose that such non-distributivity effects are not different from collectivity as in the students are a good team. In all these cases non-distributivity is a result of a set of atoms being mapped to an atom.
Evidence for this claim comes from the interpretation of predicate nominals as in (55a).

(55)  
   a. Simon and Garfunkel are singers.  
   b. Simon and Garfunkel are singing.

By contrast to (55b), where it is possible that one of the two singers is not actually singing at the moment (cf. (27)), sentence (55a) must read distributively, as equivalent to the claim that Simon is a singer and Garfunkel is a singer. I propose that this is due to the following contrast.

(56)  
   a. *This couple is a singer.  
   b. This couple is singing.

We see that the verb sing, by contrast to the noun singer, can appear felicitously with a "group referring” NP like this couple. Consequently, sentence (55b) can be true by virtue of a mapping from the set denoting the noun phrase Simon and Garfunkel to an atom like the one denoting the subject this couple in (56b). This leads to the collectivity effect in (55b). By contrast, if the set denoting Simon and Garfunkel is mapped to such a "couple atom" in (55a), what we can only get is an unacceptable reading like the one (56a) has.21

Let us summarize the assumptions above in the following informal principle.

**Principle 3** Denotations of non-quantificational noun phrases that range over sets can be mapped to denotations that range over atoms. This process is unavailable for quantifier NP denotations.

There are two points that need to be clarified in order to substantiate this principle. First, the exact nature of the difference between quantificational NPs and non-quantificational (referential) NPs should be explained. Second, the assumed mapping from sets to atoms should be semantically defined. A comprehensive discussion of these two problems would lead us too far afield. Some brief remarks are however in order.

**On non-quantificational noun phrases** One of the main motivations for assuming non-quantificational readings for noun phrases is their appearance in so-called "predicative” positions, which are normally reserved to adjectives and prepositional phrases. Consider for instance the following examples.

(57)  
   a. This woman is a teacher/the teacher/Mary.  
   b. These women are teachers/the teachers/Mary and Sue.

Partee (1987), like many other works, assumes that NPs appearing in predicative positions are interpreted using a predicative reading, which is similar to the reading of other linguistic predicates like verbs or adjectives. Partee proposes that in argument positions, all NPs still have quantificational readings as in Barwise and Cooper (1981),

21What this consideration does not explain is why nouns like singer should differ from verbs like sing to begin with, and refuse to accept "impure atoms" in their extension. This is an independent question, to which I unfortunately have no answer.
and that the connection between the two readings is achieved using type shifting principles. A further implementation of this claim comes from the recent proposals in Reinhart (1997) and Winter (1997) to treat "wide scope" indefinites using choice functions. A choice function (CF) is a function that maps any non-empty predicate to an entity in its extension. In this analysis, the reason for the island-escaping scope of the indefinite in sentence (58a) is its choice function semantics as represented in (58b).

(58) a. John will be happy if some woman arrives.
   b. \( \exists f [\text{CF}(f) \land \text{John will be happy if } f(\text{woman}) \text{ arrives}] \)

The representation in (58b) requires that there is a choice function such that John will be happy if the entity it assigns to the predicate woman arrives. This is equivalent to the claim that there is a particular woman whose arrival will make John happy. The choice function analysis derives a "wide scope" reading for the indefinite without having to syntactically pull it outside the adjunct island. What is especially relevant for our present discussion is that if this analysis is along the right track, then there is no need to derive a separate referential reading for indefinites like some woman. The independently motivated predicative reading can lead to a referential reading using the choice function analysis. A similar point holds for any noun phrase that is assumed to have a predicative reading.22

**On the mapping of sets to atoms** Once a "referential" reading is derived using choice functions for predicative NPs, we can use the Landman/Link mapping for such plural NPs that refer to set entities. Noun phrases like some students and the students can be analyzed as referring to sets, which in turn can be mapped to atoms. While the nature of this mapping is controversial, it should be stressed that most present accounts of plurals have to adopt some version of it. One reason is that the analysis of sentences like the students are the organizing committee must somehow glue together the denotations of the subject the students and the noun phrase the organizing committee. As argued extensively by Barker (1992) and Schwarzschild (1996:ch.9), the latter NP should be analyzed as referring to an atom. The former NP corresponds to a set. The semantics of the copula are, or more generally, the semantics of the predication construction, must make a semantic connection between the atom and the set. This is precisely where the Landman/Link "impure atom" strategy comes into play. The compositional sources and the exact semantic nature of this operation are not agreed upon in the literature, but the existence of such an operation in most analyses of plurality implies that with atom predicates like be the organizing committee, collectivity should be derived by some mapping from sets to atoms, and it does not depend on the possibility of the predicate to range over sets. This is the main argument of this section.

This reasoning has another welcome prediction concerning the difference between NPs with all and simple plural definites. Consider the following examples.

---

22In Winter (1998b:ch.4,1999) I propose that the noun phrases in (52) are precisely those that have such a predicative reading. The origin for this reading is claimed to be the internal structure of the DP (cf. Abney (1987)): DPs with full SPEC position are argued to be purely quantificational, NPs are treated as predicative and the intermediate D’ level is proposed to be ambiguous between the two readings using type shifting principles à la Partee.
a. The members of the organizing committee met.
b. All the members of the organizing committee met.

The organizing committee met.

Sentence (59a), but not sentence (59b), is entailed by sentence (60). This is so since it is quite impossible to imagine a situation where a committee meets but its members do not meet, though this does not mean that all of the committee members have to meet in order for (60) to be true. I propose that the origin for this contrast between (59a) and (59b) is that the former sentence, but not the latter, has a reading equivalent to (60): under the “impure atom” construal of the definite the members of the organizing committee, the set of committee members can simply be mapped to the atom standing for the committee itself. Such a process is impossible in (59b) where the only way to achieve collectivity is using the dfit strategy, which requires every committee member in (59b) to participate in the meeting.

6 Summary

Three binary distinctions were argued to trigger collectivity effects in natural language sentences:

1. The lexical semantic distinction between predicates that range over atoms and predicates that range over sets.

2. The morpho-syntactic distinction between singular number inflected predicates, which range over atoms, and plural predicates, which ambiguously range over either atoms or sets.

3. The syntactic/semantic difference between quantificational NPs and non-quantificational NPs. Non-quantificational NPs ranging over sets can be mapped to denotations ranging over “impure” atoms. Quantificational NPs cannot undergo this process.

To summarize the effects of these three principles, consider what happens in the four cases where an atom/set predicate meets a quantificational/non-quantificational NP.

1. When a set predicate like gather meets a quantificational NP like every student or all the students, the situation depends on the morphological number of the noun. Singular nouns, like all singular one place predicates in natural language, denote predicates over atoms. Plural nouns, by contrast, can denote predicates over sets of atomic entities. Determiners standardly range over atoms. Consequently, sentences in the singular like every student gathers or all the students gather get only the unacceptable interpretation, claiming that the set of students is a subset of the set of atomic entities that gather. Sentences like every committee gathers obtain their acceptable interpretation in the same way. With plurals, however, as in all the students gather, the noun can denote a predicate over sets, which does not match the atomic denotation of the determiner. This mismatch drives a type shifting operator that changes the denotation of the determiner to range over sets. Consequently, the denotation of DPs like all the students can range over sets and thus...
can combine with denotations of set predicates like *gather* to give meaningful interpretations. Sentences like *all the committees gather* are ambiguous due to the atom/set ambiguity of the plural noun and verb.

2. When an atom predicate like *be a good team* encounters a non-quantificational NP like *the students*, whose denotation ranges over sets, we get a collectivity effect. This is due to a mapping of the set of students to an impure atom. This process is a general one: it can occur with all non-quantificational NPs and all atom predicates. Thus, a non-distributivity effect like the one Dowty observes in the sentence *the children are getting up to watch cartoons* also stems from this "impure atom" strategy.

The other two possibilities are less dramatic:

3. When an atom predicate like *smile* or *be a good team* meets a quantificational NP like *all the students/committees* or *every student/committee*, we just employ the standard analysis of generalized quantifier theory. Determiners like *every* and *all* are synonyms. Due to the atomic denotations of the nouns *student(s)/committee(s)* and the verbs, the determiners *every* and *all* lead to equivalent truth conditions (see appendix A).

4. When a set predicate like *meet* combines with a non-quantificational NP like *the students*, we have two possibilities, as in many theories of plurals. One possibility is to let the quantificational denotation of the NP, which ranges over sets, to combine directly with the set predicate. A more complicated possibility is to let the impure atom strategy map the set denotation of the NP to an impure atom, as in case 1 above. This also leads to a collective interpretation, this time using the atom denotation of *meet*.

Table 2 indicates the cases where collectivity is possible and the interpretative strategies that derive it.

```
<table>
<thead>
<tr>
<th>Noun Phrase:</th>
<th>singular</th>
<th>plural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>non-quantificational</td>
<td>quantificational</td>
</tr>
<tr>
<td>Verb Phrase:</td>
<td>atom</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>set</td>
<td>no</td>
</tr>
</tbody>
</table>

i.a. = impure atoms, dfit = determiner fitting
```

Table 2: cases of collectivity

## 7 Questions for further research

This article has argued that one simple model-theoretic distinction, between atoms and their sets, is the origin for many intricate semantic phenomena with plurals. While this general thesis itself is not too controversial, the way it was used in the proposed
framework is quite different from existing alternatives and therefore (re)opens many questions for further research. One of the central claims of this paper concerns the new division between atom predicates and set predicates. What are the relations of this distinction with other lexical semantic properties of natural language predicates? For instance, what can be the reason that an adjective like numerous ranges over atoms while the adjective similar ranges over sets? A natural hypothesis is that this difference may be related to the fact that the first predicate appeals to an "inherent" cardinality property of groups, while the latter has the relational use similar to, which can easily hold of "simple" atomic individuals. As for complex predicates, many questions still need to be answered concerning the computation of their meanings. For instance, how does the adverbial together map an atom predicate like sing to the set predicate sing together? Further, is there a connection between the atom/set properties of predicates and their state/event or stage-level/individual-level classification? Another general problem concerns the role of number morphology in languages like Hungarian (cf. footnote 12), which, unlike English and other languages, show collectivity also with some singular quantificational NPs. Does this behaviour relate to the fact that English mass terms (cf. footnote 15) can also show collectivity in the singular? I believe that the answer to this question is positive. Using the recent set theoretical analysis of mass terms in Chierchia (1998), there may even be a way to simply define mass terms as set nominals in the singular, whose atoms are unaccessible for reasons along the line of Chierchia’s proposal. To see if such an approach is viable requires of course much further study. There is also more to know of the exact nature of the "impure atom" strategy. If a mapping from sets to atoms is required, as this paper argues in agreement with Landman (1989), then it may shed new light on the precise ontology needed for modeling the semantics of plurals. Elsewhere I suggest that such a mapping need not perhaps be stated in logical terms as in Landman’s article, but is perhaps a manifestation of a non-logical covert process in natural language, so it may leave the ontology of plurals simple and "flat" as in Schwarzschild (1996). There is much more to be said also on the precise semantics of collective quantification and the syntactic/semantic distinction between quantificational and non-quantificational NPs, and its implications the theory of plurals. I believe that the present work may contribute to a new examination of these questions and thus to the development of a more general theory of plurality and quantification in natural language.

Appendix: Determiner fitting

The discussion throughout this paper assumed that the origin of collectivity with set predicates and plural quantificational NPs is the type mismatch between the plural noun, ranging over sets, and the determiner, lexically ranging over atoms. This type mismatch is resolved by the determiner fitting operator, which allows the determiner to range over sets. Consider for example the following sentence.

(61) Exactly five students met.

The plural noun students and the plural verb meet both have readings where they range over sets. The noun students can denote the predicate _pl(students), ranging over sets, which for the present discussion we abbreviate by students'. The plural form
of the set predicate *meet* has as one of its two readings the lexical denotation *meet', which also ranges over sets. The determiner *exactly five* standardly denotes a function from sets of atoms (=subsets of E) to generalized quantifiers over atoms (=subsets of \(\wp(E)\)). This determiner denotation *exactly 5'* can also be standardly viewed as a relation that holds between sets of atoms whose intersection is of cardinality five. The \(dfit\) operator applies to this atomic denotation of *exactly five* and fits it to the set-based type of the denotations of *students* and *meet*. Conceptually, the result of this process is that these predicates are both lowered to predicates ranging over atoms so ordinary quantification over atoms can apply. This is obtained in two steps, which are illustrated below for sentence (61).

**Step I – intersection:** The verb denotation *meet' is modified by intersecting it with the noun denotation *students'*. We get the set *meet' \(\cap\) students'": the set of all non-empty sets of students that met. This is a manifestation of the *conservativity* of quantification in natural language, which allows to freely intersect an intransitive predicate denotation with the predicate denoting its argument’s noun.

**Step II – union:** The two sets of sets that serve as arguments of the determiner are both unioned. Thus, the set of sets students' is lowered to the set \(\cup\) students'\(\cup\) meet' \(\cap\) students', which is just the singular noun denotation student'. The intersection set of sets meet' \(\cap\) students' is lowered to \(\cup\) (meet' \(\cap\) students'): the set of students who participated in a set of students that met. This notion of participation is taken to be central to the semantics of plurals.

The result of these two steps is that sentence (61) is interpreted as claiming that the number of students who participated in a set of students that met is exactly five. This analysis has some welcome consequences. For instance, it guarantees, in agreement with intuitions, that there were no more and no less than five students who met. For further investigations of the empirical adequacy of this analysis see (Winter 1998a, 1998b:ch.5).

Formally, the definition of the \(dfit\) operator reads as follows.

(62) Let \(D\) be a function from \(\wp(E)\) to \(\wp(\wp(E))\) (i.e. a determiner over atoms). Then \(dfit(D)\) is the function from \(\wp(\wp(E))\) to \(\wp(\wp(\wp(E)))\) (i.e. a determiner over sets) such that for every two sets of sets \(A,B \subseteq \wp(E)\):

\[
B \in (dfit(D))(A) \text{ iff } \cup(A \cap B) \in D(\cup A)
\]

In words: a set of sets \(B\) is in the quantifier over sets \((dfit(D))(A)\) iff unioning all the sets that are both in \(A\) and in \(B\) gives a set of atoms that is in the quantifier over atoms that \(D\) assigns to the union of the sets in \(A\).

Let us assume the following standard definition for the determiner denotation *exactly 5'*.

(63) \(exactly_5'(A) = \{B \subseteq E : |A \cap B| = 5\}\)

In words: the denotation of *exactly five* maps every set of atoms \(A\) to the set of sets of atoms whose intersection with \(A\) is of cardinality five. Applying the above definition of the \(dfit\) to sentence (61) using this standard analysis leads to the following meaning derivation.
In words: the number of students who participated in a student meeting is five.

Now we can formally observe a fact that was crucial for the analysis in section 4. It was claimed with regards to sentences (47b) and (47d) that when the main predicate in a sentence is an atom predicate, the analysis we get using $dfit$ is equivalent to the standard distributive analysis, as intuitively required. For instance, with the atom predicate elected Clinton, no quantificational NP can show collectivity. Consider as an example the contrast between (61) above and the following sentence.

(65) *Exactly five students elected Clinton.

Under the sets of sets analysis of the plural noun students, the analysis we get for (65) is analogous to the analysis of sentence (61) above. However, unlike the situation with the verb meet in (61), now even when the denotation of the predicate elected Clinton ranges over sets, it does not generate collectivity. This is illustrated in the following analysis of (65).

\[
\begin{align*}
(66) \quad pl(\text{elect}_C') \in (dfit(\text{exactly}_5'))(\text{students'}) \\
\Leftrightarrow &\{\{x \in E : \exists A \subseteq \text{student'}[x \in A \land A \subseteq \text{student'} \land A \in \text{meet'}]\} \subseteq \text{student'} \land A \in \text{meet'}\} = 5 \\
\Leftrightarrow &\{\{x \in E : \exists A \subseteq \text{student'}[x \in A \land A \subseteq \text{elect}_C']\} \subseteq \text{student'} \land A \in \text{elect}_C'\} = 5 \\
\Leftrightarrow &|\text{student'} \cap \text{elect}_C'| = 5 \\
\end{align*}
\]

This reading is nonsensical as it counts the total number of students who individually "elected Clinton". Incidentally, it is identical to the reading we get without the application of $dfit$ and the two applications of $pl$. The (provably general) conclusion is that the $dfit$ operator within plural quantificational NPs correctly does not generate collectivity with atom predicates.

References


Computer Science
Technion
Haifa 32000
Israel
E-mail: winter@cs.technion.ac.il
WWW: http://www.cs.technion.ac.il/~winter