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## A Vagueness Approach to the Mass/Count Distinction

Haitao Cai  
hcai@sas.upenn.edu

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## 1 Introduction

In many languages such as English and German, there are a variety of properties that characterize the grammatical mass/count distinction, namely, the distinction between mass nouns and count nouns. These properties can be observed wherever the mass/count distinction is detected, though this is not strictly the case (Chierchia 1998:55).

One of the most salient among these properties is the restriction of plural morphology to count nouns. In English, only count nouns can normally end with the suffix **-(e)s** marking plurality.

- (1) a. The computer is connected to two devices.  
b. \* The computer is connected to two equipments.
- (2) a. \* There are three waters on the table.  
b. There are three glasses of water on the table.

The asterisk merely indicates ungrammaticality of sentences *by default*, since some of them can be grammaticized in particular contexts (Chierchia 1998, Bale and Barner 2009). For instance, an utterance of (2a) is acceptable in a bar where the amount of “each” water is publicly known, that is, usually a glass of water.

Another property marking the distinction between mass nouns and count nouns arises in forming a noun phrase with numerals and with(out) classifiers. Specifically, count nouns can immediately follow numeral determiners whereas mass nouns cannot; in contrast, mass nouns can be associated with numerals with intermediate classifiers but count nouns normally cannot (Rothstein 2010:346), as is illustrated by (3).

- (3) a. two tables / \* two furniture(s)  
b. two pieces of furniture / \* two pieces of table

Moreover, some determiners select only mass nouns (e.g., (4a)); some require count nouns (e.g., (4b)); some select plural count nouns and mass nouns (e.g., (4c)), and others are insensitive to the mass/count distinction and the singular/plural distinction (e.g., (4d)).

- (4) a. much snow/\*chair, little snow/\*chair  
b. many planes/\*rice, every plane/\*rice  
c. a lot of snow/planes/\*chair  
d. some ice/questions/member

Despite the fact that most count nouns denote entities which have salient units or atoms while mass nouns mostly denote entities having no salient atoms, the exceptions are too many to be disregarded, such as **furniture** and **equipment**. Particularly, the mass/count distinction can be independent of the structure of objects. Specifically, a count noun can be nearly synonymous to a mass noun (Chierchia 1998:56).

- (5) a. shoes vs. footwear  
b. clothes vs. clothing  
c. carpets vs. carpeting

In addition, it is subject to cross-linguistic variation which nouns are count nouns and which are mass nouns. For instance, **bean** is a count noun in English but **fasole** is a mass noun in Rumanian (Chierchia 2010:140).

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What makes the mass/count distinction more interesting is the conversion between these two types of nouns. Sentence (2a) illustrates the count use of a mass noun. A count noun can also have mass use. For instance, (6) is another way of saying that the ingredients for making the cake include bananas.

- (6) There is banana in the cake.

Crucially, the grammatical mass/count distinction is deeply connected to the semantics of nominals. For instance, the semantic representation of a count noun essentially differs from that of its mass counterpart even if they have the same noun stem (e.g., **rock(s)**, **rope(s)**). This claim is evidenced by the test based on comparative constructions. Barner and Snedeker (2005) discover that when people are asked to make a comparison concerning the quantity of objects, they are inclined to exploit different information according to whether it is grammatically a mass noun or count noun at issue.

- (7) a. John brought more ropes than Mary did.  
 b. John brought more rope than Mary did.  
 (8) a. John brought more rocks than Mary did.  
 b. John brought more rock than Mary did.

Although the count use of **ropes** often denotes the same physical objects as does the mass use of **rope** and the two forms could be used interchangeably (with adjustment of preceding determiners) in many situations, sentence (7a) is evaluated with respect to number of individuals in contrast with (7b)'s being evaluated according to volume. Sentences (8a) and (8b) are analogous.

This paper aims to contribute toward a deeper understanding of the semantic difference between mass nouns and count nouns, which will be justified by the various properties introduced above. The outline of this paper is as follows.

Section 2 Two primitive formal representations of aggregations, *sum* and *plurality*, will be introduced, the contrast between which is central to the semantic analysis of the mass/count distinction.

Section 3 Although the mass/count distinction cannot be characterized by natural atomicity of entities denoted by nouns, the interpretation of count nouns normally involves the identification of atomic objects in contrast with atomless objects and aggregations of atomic objects. Therefore, the notion of *atomic objects* is to be defined and it will be argued that multiple properties of referents, such as indivisibility and self-connectedness, are needed to define atomicity.

Section 4 Based on the natural atomicity defined in Section 3, the denotations of mass nouns and count nouns will be formally represented.

## 2 Sum/Fusion versus Plurality

The core meaning of a noun stem **P** is a number-neutral property *P* (Chierchia 2010:139). That is, *P* consists of all entities that have the property of being *P*, regardless of quantity. Therefore, if **P** denotes objects with salient atomic structures, *P* contains both *P*-atoms (i.e., individual/atomic **Ps**) and aggregations of *P*-atoms. Then, what is an atomic object having the property of being *P*? More specifically, given a noun stem **P**, how are atomic **Ps** derived from *P*? The atomicity to be first defined is *natural* atomicity. That is, it will be addressed which entities falling under *P* are *perceived* as *P*-atoms, which is distinct from whether they are *referred to* as *P*-atoms. It has been widely noted that entities having intuitive atomic structures may be referred to as being atomless (Chierchia 1998, Bale and Barner 2009, Rothstein 2010). Before defining natural atomicity, it needs to be specified what is an aggregation falling under *P*.

One candidate for this role is *plurality*, which is typically employed to represent entities falling under the denotations of plural noun phrases (Nicolas 2008:225). Formally,  $a \sqcup a'$  is the plurality

consisting of exactly  $a$  and  $a'$ , and is also the denotation of the noun phrase **A and A'** where  $[[\mathbf{A}]] = a$  and  $[[\mathbf{A}']] = a'$ . The components contained in a plurality are grammatically accessible. For instance, sentence (9) can mean that John had a glass of wine and Mary had another.

(9) John and Mary had a glass of wine.

Let  $\trianglelefteq$  denote the relation of *among* between pluralities and their components. Formally,

$$a \trianglelefteq b \text{ iff } \exists A[a \in A \wedge b = \bigsqcup A]$$

In contrast, another candidate, *mereological sum* or '*fusion*' essentially comes with unity.<sup>1</sup> For example, the fusion of  $a$  and  $a'$  (notation:  $a \oplus a'$ ) is used to represent the aggregation of  $a$  and  $a'$  as a single entity, though possibly physically discrete (e.g.,  $a$  does not overlap with  $a'$ ). The unity of  $a \oplus a'$  can be formulated as (10).

(10)  $\forall d[d \trianglelefteq a \oplus a' \rightarrow d = a \oplus a']$

Two different pluralities  $g_1$  and  $g_2$  can have the same mereological sum. For instance, the upper half of a glass of water and the lower half form a plurality that is not identical to the plurality formed by the left half and the right half, despite the mereological sums of the two pluralities being the same.

Let  $\leq$  denote the relation (*mereological*) *part-of*, which can be defined in terms of sum/fusion as follows.

$$a \leq b \text{ iff } a \oplus b = b$$

Moreover,  $a$  is a *proper part of*  $b$  (notation:  $a < b$ ) iff  $a \leq b$  and  $a \neq b$ . A simple example illustrating the difference between *among* and *part-of* is as follows. Let  $a$  and  $b$  be two chairs and  $a'$  a leg of  $a$ . Then,  $a'$  stands in the mereological part-of relation  $\leq$  to  $a$  as well as to  $a \oplus b$ , formally,  $a' \leq a$  and  $a' \leq a \oplus b$ . In contrast, *among*  $\trianglelefteq$  holds between  $a$  and  $a \sqcup b$  but not between  $a'$  and  $a$  or between  $a'$  and  $a \sqcup b$ . More generally,  $\leq$  is transitive while  $\trianglelefteq$  is not.

Considering the formal properties of sum and plurality, the number-neutral property  $P$  associated with each noun stem  $\mathbf{P}$  contains no pluralities. Namely, each element of  $P$  comes with unity. This statement immediately follows from the following claims.

*Claim 1* If there exists a  $P$  that has pluralities in its extension, the properties associated with (naturally) atomic nouns and those associated with atomless nouns should both contain pluralities.

*Claim 2* The properties associated with prototypical mass nouns (e.g., **water** and **sand**) cannot contain pluralities in their extensions.

*Claim 1* can be justified as follows. Under the supposition that properties associated with noun stems can contain pluralities, the most plausible representation of the property  $P$  associated with an atomic noun  $\mathbf{P}$  is that it consists of atomic  $\mathbf{P}$ s and pluralities of atomic  $\mathbf{P}$ s. If  $P$  does not contain pluralities because of the natural atomlessness of  $\mathbf{P}$ , the derivation of natural atomicity would be trivialized, since the absence of the atomic entities denoted by  $\mathbf{P}$  can be simply determined by the absence of pluralities in  $P$ , which reduces the notion of atomicity to mere stipulation of the presence of pluralities, and which thus does not shed any light on this notion.

*Claim 2* is forced by the ungrammaticality of taking a naturally atomless mass DP as the antecedent of a reciprocal. Given that each atomless mass noun stem  $\mathbf{P}$  is also associated with a property  $P$  containing pluralities, it will be unexpected that a single mass noun phrase cannot be the antecedent of a reciprocal while a conjunction of two mass noun phrases can, because the components of the plurality denoted by **the water** should be accessible, as are John and Mary in the denotation of **John and Mary**. This is illustrated by (11a) and (11b).

(11) a. \*The water repels each other.

<sup>1</sup>See Champollion and Krifka 2014 for an axiomatic characterization of *sum*.

- b. The water and the oil repel each other.

Therefore, it is untenable to assume that the properties associated with noun stems contain pluralities. In other words, each element comes with unity, which is accountable for the ungrammaticality of (11a). That is, the *aggregation* involved in the representation of number-neutral properties is sum/fusion, rather than pluralities.

### 3 Natural Atomicity

#### 3.1 Vagueness

Chierchia (2010) comes up with an interpretation of each noun stem in terms of vagueness. Basically, the borderline between  $P$ -objects and non- $P$ -objects is hardly strict or accurate. For instance, if a tree is being cut bit by bit, there will come a point where it is no longer certain that the remainder is still a tree. Moreover, at that point, it is also often not the case that the remainder is clearly not a tree. In other words, there is such a class of objects that are neither obviously trees nor undoubtedly non-trees. This type of vagueness is said to be *inherent* since there is no criterion that can accurately distinguish trees from entities that are not trees. Also, the differentiation varies from context to context.

Therefore, the property  $P_c$  associated with  $\mathbf{P}$  relative to a context  $c$  is threefold: a positive extension  $P^+_c$  consisting of objects definitely being  $P$ , a negative extension  $P^-_c$  of those which are definitely not  $P$  and a vagueness band  $P^*_c$  being the gap characterizing the inherently vague boundary between  $P$ -objects and non- $P$ -objects, since there are objects that are hard to classify as  $P$ -objects or non- $P$ -objects with certainty (Chierchia 2010:118–119). The subscript indicating the context at issue may be omitted when  $c$  denotes a context in general.

#### 3.2 Indivisibility

Back to the question: how are  $P$ -atoms derived from  $P$ ? Chierchia (1998) and Rothstein (2010) stipulate a pregiven set of atoms for all nouns though the atoms may not be intuitively accessible to perception (e.g., **water**, **air**). But this paper aims to derive atomic objects instead of taking atomic objects as pregiven, since it is not self-evident what atomic objects are in general.

For those analyses in which atomic objects are derived rather than pregiven, the number-neutral property associated with a noun stem is usually illustrated by graphs such as (12). Specifically, suppose there are only three cats  $d$ ,  $d'$  and  $d''$  in the world, (12) represents the number-neutral property CAT (let words in capital letters denote number-neutral properties).

$$(12) \quad \begin{array}{ccc} d \oplus d' \oplus d'' & & \\ d \oplus d' & d' \oplus d'' & d \oplus d'' \\ d & d' & d'' \end{array}$$

Given this type of representation of number-neutral properties, a widely accepted proposal is as follows (Bale and Barner 2009, Chierchia 2010).

- (13) Atomic  $P$ -objects are minimal elements of  $P^+_c$ , that is, elements that do not contain proper parts falling under the number-neutral property  $P$ .

This proposal appears to capture the atomic or individual cats in (12). However, it is actually *incompatible* with the inherent vagueness of the boundary of  $P^+_c$ . Basically, an atomic object can still be atomic even if some tiny piece is chipped off from it. But under the definition (13), an intuitively atomic cat may not be a CAT-atom because it remains a cat even if it loses some hair which results in a proper part of the initial cat. Two possible attempts to save (13) are as follows.

*Attempt 1:* Make the assumption that the proper-part relation at issue only holds between atomic objects and their aggregations but not between atomic objects and their proper parts. Nonetheless,

this assumption is begging the question as it is exactly the notion of atomic objects that is in question. To obtain the restricted proper-part relation, it should have already been known what an atomic object is, so that no proper part of an atomic object will be taken into account (because an atomic cat can have a proper part which is also a cat).

*Attempt 2:* Assume that CAT could be simply represented as graphs such as (12). However, the representation in (12) over-simplifies the interpretation of **cat**: every proficient speaker of English knows that the individuals and aggregations contained in (12) will remain falling under CAT<sup>+</sup> even if they undergo some minor changes. Therefore, (12) cannot represent people's understanding of **cat**. The acquisition of **cat** should, within each specific situation, enable a speaker to identify those objects that fall under CAT as long as they manifest characteristic features of cats.

Therefore, neither of the attempts is successful. Instead, I propose the following definition.

**Definition 1.** An individual  $d$  is an *atomic P-object* (or *P-atom*, notation:  $d \in P^{\text{AT}}_c$ ) in context  $c$  iff it is such a  $P$ -object that any division of  $d$  will produce non- $P$ -objects, formally,

- (14)  $d \in P^+_c$  and for all non-overlapping  $d', d''$  (i.e., there is no  $x$  satisfying both  $x \leq d'$  and  $x \leq d''$ ) such that  $d', d'' < d$ , it holds that  $d' \in P^-_c$  or  $d'' \in P^-_c$ .

As an illustration, no atomic cat can be further divided into multiple cats, while all sums or fusions of multiple cats can. It is analogous for other naturally atomic nouns such as **tree**, **car** and **chair**. Also, there is no conceptual circularity of presupposing the identification of atomic objects that should be defined.

Furthermore, the indivisibility approach formulated as (14) also facilitates the resolution of the tension between the intuitive atomlessness of water and the existence of water molecules which are considered as the basic chemical units of water. In other words, water is not infinitely divisible, and specifically, if some water is divided bit by bit, there will finally come the point when the residue is a single water molecule and therefore any division of it will necessarily produce entities falling under WATER<sup>-</sup>. Nonetheless, water is still normally perceived as an atomless substance.

A seemingly plausible explanation is that the atomic constituents of water (i.e., water molecules) are too small to be perceived without advanced technology. Thus, people talk about water *as if* it has no atomic elements. However, in order to classify water as an atomless substance, is it necessary to ignore its physically existent units? Actually, this ignorance is not necessary.

This point can be justified by a close scrutiny of the concept of water that is displayed by simple declarative sentences. The truth or falsity of a declarative sentence can reflect the identification of each particular object, e.g., whether an object is water. Specifically, (15) can be used to describe a glass filled with water, a pond or a river.

- (15) There is (some) water.

However, consider the situation where there is a bottle of liquid containing only a small cluster of water molecules, (16) and (17) are intuitively true and are definitely preferred over (15).

- (16) There are some water molecules.  
(17) There is a cluster of water molecules.

More generally, it is unclear whether (15) is a felicitous description of the existence of a single water molecule or a small cluster of water molecules. The most plausible interpretation of the uncertainty regarding (15) as a description of the situation at issue is: it is vague whether the small cluster of water molecules can be counted as water.

Hence, on the one hand, in usual contexts, it is hard to identify a single water molecule or a small cluster of water molecules as water with certainty, as has been illustrated by the ambiguity about (15). On the other hand, it is untenable to claim that small clusters of water molecules are not water, since they are the basic constituents of water. Based on these two considerations, it seems pretty reasonable to think of single water molecules and their small clusters as elements of WATER\* (i.e., the vagueness band of WATER), which consists of objects that cannot be identified as water or non-water with certainty.

Thus, the perception of water as an atomless substance can be justified under Definition 1, which re-defines the minimality involved in the notion of atomic objects and which requires each atomic  $P$ -object (where  $P$  is an arbitrary number-neutral property) to be such that any division of it will result in at least one element of the negative extension of  $P$  (i.e., an object that is definitely not  $P$ ). This definition is not satisfied by water. To see this, it suffices to think about those elements falling under the positive extension of WATER, since by Definition 1, an atomic object of WATER, if there is any, must be an element of WATER<sup>+</sup>. As has been argued above, each element  $d$  of WATER<sup>+</sup> is an aggregation of water molecules that is sufficiently large. Thus, dividing  $d$  into two arbitrary sub-clusters  $d'$  and  $d''$  of water molecules (or single water molecules),  $d'$  falls under either WATER<sup>+</sup> (if it is sufficiently large) or WATER\* (otherwise), and it is the same for  $d''$ . Therefore, neither  $d'$  nor  $d''$  is an element of WATER<sup>-</sup>, which implies that  $d$  is not an atomic element of WATER.<sup>2</sup>

To sum up, it is not contingent whether the atomic structure is available in the denotation of a noun  $\mathbf{P}$ . Instead, it has its root in the number-neutral property  $P$  associated with  $\mathbf{P}$ , and specifically, what is definitely  $P$ , what is definitely not  $P$  and what is on the borderline. As a consequence, it is not illuminating to stipulate the presence and absence of atomic objects in the denotations of nouns, which is common to many previous analyses.

### 3.3 Self-Connectedness

The atomic objects falling under the denotations of certain nouns (e.g., **rope** and **rock**) are homogeneous in the sense that each of them can be further divided into multiple atomic objects that are still elements of the denotation of the noun in question. Specifically, a rope can be cut into two segments both of which are also ropes, and a rock can be broken into fragments all of which are rocks. Grammatically, these nouns are *flexible* in that they have both a mass form and a count form by default. For instance, the mass **rock**<sub>mass</sub> denotes certain solid mineral matter or material, while the count **rock**<sub>count</sub> denotes a large piece or a large mass of this matter/material. As a consequence of the divisibility of atomic entities denoted by these flexible nouns, the indivisibility approach (14) does not apply to these nouns.

Instead, the atomic objects denoted by them can be defined by making use of the term *integrated whole* proposed by Moltmann (1998) (e.g., a rock is self-connected and thus an integrated whole, otherwise it cannot be counted as *one* piece). Given an appropriate binary relation  $R$  (e.g.,  $R$  is a non-logical relation), let  $R_{\text{tr}}$  be the transitive closure of  $R$ .

**Definition 2.** Given an object  $x$ ,  $x$  is an *R-integrated whole* (notation:  $R - \text{INT-WH}(x)$ ) iff

- (i) for all objects  $y, z < x$ ,  $R_{\text{tr}}(y, z)$ , and
- (ii) there are no objects  $u, v$  such that  $u < x$ ,  $v \not< x$  and  $R_{\text{tr}}(u, v)$ .

As an illustration, let  $R$  be the relation of *being (directly) connected* between each adjacent pair of the parts of a rock, then  $R_{\text{tr}}$  characterizes the relation between every pair of the parts of each rock, since any two parts are either directly connected or intermediated by a third one which is directly connected to the two parts. Therefore,  $R_{\text{tr}}$  holds between each pair of the parts of each rock but never between any two parts of two rocks. It is analogous for **rope**.

However, self-connectedness is not the only constraint on the atomic entities denoted by flexible nouns such as **rope** and **rock**. Instead, it is normally subject to further constraints on the shape and the size, though the constraints are vague and context-dependent. For instance, a thin stick made of rock cannot be called *a* rock, despite rock being the only substance contained in the stick. In addition, a small grain of rock is not *a* rock, either. These constraints are sensible or necessary if it is assumed that (i) a primary function of atomic objects is to facilitate counting and thus measuring the overall quantity of their aggregations, and that (ii) counting requires units. If a set of entities have no regular shapes or sizes at all and what they have in common is nothing other than their material, it

<sup>2</sup>As has been stated at the beginning of this section, whether an entity is perceived as consisting of atoms is distinct from whether it is referred to as being composed of atoms. For instance, FURNITURE<sup>AT</sup> is not empty though its elements are referred to by **furniture** as being atomless.



is usually senseless to take them as counting units (unless they are denoted by nouns such as **thing**). These constraints are usually missing in existing theories (e.g., Bale and Barner 2009), but they are actually characteristic properties of many atomic entities.

Formally, let  $\chi$  be the unary predicate representing the constraints on the shape and the size of each rock, the atomic elements of ROCK is defined as follows.

$$(18) \text{ ROCK}^{\text{AT}}_c = \{d \in \text{ROCK}^+_c \mid \text{INT-WH}(d) \wedge \chi(d)\}$$

Although many atomic entities derived by the mechanism formulated as (14) can be alternatively derived by the self-connectedness approach, the indivisibility approach (14) is still a necessary member of the family of mechanisms for atom derivation. Casati and Varzi (1999) point out that many atomic objects do not satisfy the condition of self-connectedness, e.g., bikinis, three-piece suits and teapot sets. Consider two teapots  $t_1$  and  $t_2$  and two cups  $d_1$  and  $d_2$ . Suppose that each teapot set consists of one teapot and one cup, and that teapots and cups are produced separately, which implies that there are not salient characteristic relations (e.g., self-connectedness) between  $t_1$  and  $d_1$  that do not hold between  $t_1$  and  $d_2$ . Hence,  $t_1$  and  $d_1$  can form a teapot set, but  $t_1$  and  $d_2$  can also form a teapot set without standing in any connectedness relation to each other.

In contrast, this observation about teapot sets is perfectly compatible with the indivisibility approach. Formally, it is the case that

$$t_1 \oplus d_1, t_1 \oplus d_2, t_2 \oplus d_1, t_2 \oplus d_2 \in \text{TEAPOT-SET}^{\text{AT}}_c$$

This paper does not aim to enumerate all mechanisms for deriving atomic objects. What is being shown is that there are systematic methods that can be used to specify the (existence of) atomic objects denoted by nouns, that is, deriving the atomic objects falling under the denotation of each noun from the number-neutral property associated with the noun stem, though there is no such unique method. Therefore, it is unilluminating to assume a set of ‘salient’ atomic objects.

However, two questions naturally arise:

- (a) Given an arbitrary noun that denotes objects with salient atomic structures, how is it determined which mechanism for atom derivation should be applied?
- (b) Specifically, although it has been argued that water is atomless with respect to Definition 1, a portion of water can be self-connected and thus may qualify as a WATER-atom.

The second question could be addressed first. As has been shown, for those nouns to which the self-connectedness mechanism applies, atomic entities may not be defined by self-connectedness alone. Considering the huge diversity of shape, size and form of water, it is hard for water to satisfy any constraints on shape or size. Therefore, it is generally unreasonable to talk about an element of  $\text{WATER}^+_c$  as a WATER-atom. However, as has been mentioned in Section 1, water can be used as a count noun in particular scenarios. For instance, in a restaurant or a bar, when each portion of water is of a regular volume and is contained in a glass with a uniform shape, such a portion of water is referred to by **a water**.

As for Question (a), the specific mechanism for atom derivation comes as a core component of the lexical meaning of nouns. That is, the lexical meaning of each noun **P** consists of a number-neutral property  $P$  and the mechanism(s) for deriving atomic elements of  $P^+_c$  in context  $c$ . What is encoded in the former is nothing else than which entities are  $P$  (i.e., have the property of being  $P$ ), whereas the latter specifies the type of atomicity of  $P$ .

As an illustration, a chair is a seat that has legs and can support people’s bodies. Therefore, chairs are characterized by indivisibility, though self-connectedness also applies. That is, a chair normally cannot be divided into multiple objects each of which is still a seat that has legs and can support people’s bodies. On the other hand, the natural atomlessness of entities denoted by prototypical mass nouns such as **water** and **air** is not justified by simply assuming that the lexical meanings of these nouns contain no mechanism for atom derivation; instead, it is a consequence of the fact that no mechanism applies to these nouns, as has been argued above.

Nevertheless, these mechanisms are not formal paraphrases of the dictionary meanings. Rather,

these mechanisms *derive* atomic entities from each number-neutral property  $P$ . They shed light on the notions of natural atomicity associated with different nouns.

Furthermore, for each number-neutral property  $P$ , the specific mechanism for atom derivation correlates with whether there are contexts in which  $P$ -atoms can be referred to as *atomless* matter being  $P$  by  $\mathbf{P}_{\text{mass}}$ . The contrast between (19) and (20) serves as an illustration. Specifically, (19) can describe a pile of rocks where the **rock** denotes rock as a material (i.e., coherent and atomless matter), while (20) cannot be used to characterize a tower made of chairs, regardless of the number of the chairs. Rather, the chairs, which the tower is made of, can be referred to by **chairs** as units rather than atomless matter being CHAIR.<sup>3</sup>

- (19) The pile is made of rock.  
 (20) The tower is made of chair.

Particularly, this contrast cannot be simply explained by the fact that **rock** is a flexible noun while **chair** is a predominantly count noun, since **chair** can be used as a mass noun though the mass usage is constrained to a few particular contexts. For instance, if one or multiple chairs are broken into small fragments, (21) will be more or less acceptable to most native English speakers.

- (21) There is/\*are chair all over the floor.

Hence, the mechanisms for atom derivation that are associated with each noun stem  $\mathbf{P}$  are not chosen randomly. Instead, the determination correlates with the felicity of referring to  $P$ -atoms as atomless matter having the property of being  $P$  by  $\mathbf{P}_{\text{mass}}$ .

#### 4 Formalizing Denotation

Based on the mechanisms for deriving atomic entities, the denotations of nouns could be formally spelled out. Although natural atomicity of referents does not strictly entail a noun's being count, count nouns normally denote entities with atomic structures, no matter whether the atomicity comes as part of the lexical semantics (e.g., **cat**, **car** and **chair**) or only arises in particular contexts (e.g., **a water**). For each noun stem  $\mathbf{P}$  associated with a number-neutral property  $P$  such that  $P^{\text{AT}}_c \neq \emptyset$ , the interpretation of the singular count  $\mathbf{P}_{\text{count}}$  can be defined as follows, which is analogous to what is proposed by Rothstein (2010).

$$(22) \quad \llbracket \mathbf{P}_{\text{count}} \rrbracket_c =_{\text{def}} \{ \langle d, c \rangle \mid d \in P^{\text{AT}}_c \}$$

Each atomic entity is indexed by the context  $c$  at issue, which formally distinguishes atomic entities from non-atomic ones. The atoms of the form  $\langle d, c \rangle$  are called *count atoms* (Rothstein 2010:363). Basically, count atoms represent entities that are *referred to as* being atoms.

In contrast, the interpretation of a mass noun is identical to the positive extension of its associated number-neutral property without being indexed by the context.

$$(23) \quad \llbracket \mathbf{P}_{\text{mass}} \rrbracket_c =_{\text{def}} P^+_c$$

Many existing theories of the mass/count distinction use mereological sum to represent plurality. Although it is extremely hard, if not impossible, to provide a decisive argument against this approach, it is still obvious that

- the essential unity of mereological sum is incompatible with plurality, and
- most theories following this proposal can be shown to be problematic because of their failure to capture the semantic properties of pluralities in relation to atomic objects. Such difficulties have also been pointed out by Nicolas (2008).

Therefore, the interpretation of plural count nouns  $\mathbf{Ps}$  should be instead obtained by applying the function PL to  $\llbracket \mathbf{P}_{\text{count}} \rrbracket_c$ , which can be defined in terms of *plurality formation* (notation:  $\llbracket \_ \rrbracket$ ). Basically, each element of  $\llbracket \mathbf{Ps} \rrbracket_c$  is a plurality of count atoms that are of the form  $\langle d, c \rangle$ .

<sup>3</sup>The denotation of **chair**<sub>mass</sub> is semantically represented as being atomless, which is justified by properties such as singular verb agreement (e.g., (21)).

$$(24) \quad \text{PL}(\llbracket \mathbf{P}_{\text{count}} \rrbracket_c) =_{\text{def}} \{ \sqcup S \mid S \subseteq \llbracket \mathbf{P}_{\text{count}} \rrbracket_c \wedge S \neq \emptyset \}$$

The constraint of non-overlap applies by default, that is, each  $S$  involved in (24) contains no overlapping count atoms.<sup>4</sup>

Rothstein (2010) assumes that numerals only apply to sets of pluralities built from entities of the form  $\langle d, c \rangle$  via plurality formation, thus the fact that numerals (without intermediate classifiers) can only form DPs with count NPs but not mass NPs is naturally derived from the contrast between (22) and (23) as a consequence of type match/mismatch. Analogously, the distribution of other determiners can also be explained. The following discussions will not be focused on these issues.

There is a class of atomic entities that come with built-in plurality, namely, those denoted by *group nouns* (Landman 1989a,b, Rothstein 2010) such as **deck (of cards)** and **class (of students)**. According to (25), what is numbered is individual cards though the cards form a single deck. This reading is most salient since it is pragmatically trivial to number a single deck. In addition, entities denoted by group noun phrases are also atomic (Link 2002:129). For instance, what (26) describes is that the *decks* of cards, rather than individual cards, are numbered.

(25) A deck of cards on the table is numbered consecutively.

(26) The decks of cards on the table are numbered consecutively.

Both Chierchia (1998) and Rothstein (2010) assume a special class of primitive atomic entities that formally constitute the denotations of group nouns, and the atomic constituents of them (e.g., the cards contained in a deck) could be retrieved. However, this class of primitive entities may well be redundant. Rather, I propose that the denotations of group noun phrases (e.g., **deck of cards**) can be represented as a combination of atomicity and plurality, formally, (28), which is formulated in terms of the extraction function  $\pi_1$  that was initially defined by Rothstein (2010).

$$(27) \quad \text{a. } \pi_1(\langle d, c \rangle) = d$$

$$\text{b. } \pi_1(\sqcup S) = \sqcup \{ \pi_1(a) \mid a \in S \}$$

$$(28) \quad \llbracket \mathbf{deck\ of\ cards} \rrbracket_c = \{ \langle \pi_1(a), c \rangle \mid a \in \text{PL}(\llbracket \mathbf{card} \rrbracket_c) \wedge \varphi(a) \}$$

$\varphi$  is the description of the group members encoded in each group noun, such as the number of cards in a deck. Then,  $\llbracket \mathbf{deck} \rrbracket_c$  is a function mapping pluralities to groups of the form  $\langle \sqcup A, c \rangle$  from which atomic group members can be retrieved via  $\pi_1$ .

## 5 Conclusion

It has been argued that both mereological sum/fusion and plurality are needed to represent the denotations of nominals. The former can represent an aggregation of atoms as being an atomless unity, whereas the latter preserves the accessibility of (atomic) components. Moreover, natural atomicity is defined based on the number-neutral property associated with each noun stem. The particular type of natural atomicity encoded in each count noun is characterized by the specific mechanism for atom derivation that comes as part of the core meaning of the noun stem.

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<sup>4</sup>See Rothstein 2010 for more detailed discussion.

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Department of Linguistics  
University of Pennsylvania  
Philadelphia, PA 19104  
[hcai@babel.ling.upenn.edu](mailto:hcai@babel.ling.upenn.edu)