Homogeneity and the Mass/Count Distinction[1]

Haitao Cai — University of Pennsylvania

Abstract. Predominantly count nouns can have a mass form. The universal grinder proposed by Pelletier (1975) for the semantics of mass forms of predominantly count nouns have been widely adopted. However, I argue that grinding is not part of the semantics; instead, it is an implicature triggered by formal atomlessness encoded in mass forms. This proposal is in accordance with the observation that the mass/count distinction concerns the way nominals refer, rather than the structures of referents. However, the felicity of using the mass form of a predominantly count noun can be influenced by the homogeneity of the referents.

Keywords: formal atomlessness, homogeneity, mass/count.

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. For instance, the following properties are among the best known:

– restriction of plural morphology to count nouns;

(1) a. The computer is connected to two devices.
b. * The computer is connected to two equipments.

– distribution of determiners;

(2) a. much snow/*chair, little snow/*chair
b. many planes/*rice, every plane/*rice

– eligibility of associating with numerals with/without intermediate classifiers.

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

[1]Special thanks go to Florian Schwarz, for his insightful comments on the analyses. The implementation of the experiment in Ibex Farm relies on assistance from Jérémy Zehr. My conversations with Lucas Champollion on mass terms are extremely helpful. Additionally, this article greatly benefits from David Embick's questioning and my cohort members' feedback in LING-500 at the University of Pennsylvania. I also want to thank my advisor Robin Clark for his guidance. Moreover, I appreciate the valuable feedback from the audience at Sinn und Bedeutung 20. All errors are mine.

Although the mass/count distinction is primarily characterized by various grammatical properties, it is also deeply encoded in the semantics of nominals. 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**, **rope**). 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 quantity of objects, they are inclined to exploit different types of information, depending on whether it is grammatically a mass noun or a count noun that is at issue.

For instance, the plural form **rocks** can denote the same physical objects as does the mass use of **rock** in many situations. However, sentence (4a) is evaluated with respect to number of individuals in contrast with (4b)'s being evaluated according to volume, even if people are shown the same scenario.

(4) a. John has more rocks than Mary does.
b. John has more rock than Mary does.

Despite the fact that most count nouns denote entities which consist of 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 structures of objects. Specifically, a count noun can be nearly synonymous to a mass noun (Chierchia 1998: 56), as is illustrated by (5). Therefore, it is reasonable to assume that the mass/count distinction concerns the way objects are referred to, but not the presence/absence of their atomic structures (Rothstein 2010).

(5) shoes vs. footwear

What makes the mass/count distinction more interesting is the conversion between the two types of nouns. Sentence (6a) illustrates the count use of a mass noun. An utterance of (6a) is acceptable in a bar where the quantity of "a" water is publicly known, that is, usually a glass of water, though (6a) is not perfectly grammatical by default. In other words, sentence (6a) is a short version of (6b).

(6) a. Can I have a water?
b. Can I have a glass of water?

A count noun can also have mass use. For instance, sentence (7) is another way of saying that the ingredients for making the cake include bananas.

(7) There is banana in the cake.

This article is devoted to investigation of the latter type of conversion. It has been widely noticed that it is usually infelicitous to refer to objects falling under the denotation of a predominantly count noun $\mathbf{N}_{\mathbf{count}}$ by its mass form $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$. For example, sentence (8) is infelicitous if what is on the floor is a brand new bicycle. The felicity could be significantly enhanced if the scenario in question contains fragments of a disassembled bicycle on the floor.

(8) There is bicycle all over the floor.

Based on such phenomena, atomic objects denoted by $\mathbf{N}_{\mathbf{count}}$ are strictly excluded from the denotation of $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ in many, if not all, existing analyses (Cheng et al. 2008, Rothstein 2010). This line of thoughts could be traced back to Pelletier 1975 and Pelletier and Schubert 1989, who introduced the so-called *universal grinder* (to be reviewed in Section 3).

However, I argue that the exclusion of atomic **N**s from $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ is not part of the semantics of $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$. Instead, it is an implicature which is tightly bound with $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$. This proposal is also in line with the observation that the mass/count distinction concerns the way objects are referred to, but not the presence/absence of their atomic structures (Rothstein 2010).

In the next section, I will introduce two distinct representations of aggregations, which underlie the semantic representations of the mass/count distinction in general. In Section 3, I will briefly review the proposal of the universal grinder and provide evidence against encoding natural atomlessness in the semantics. In Section 4, I will (i) present my analysis of $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$'s preference for natural atomlessness (illustrated by (8)) in terms of formal atomlessness and (ii) account for the variation in felicity of using $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ across categories of nouns based on my refined definition of homogeneity.

2. Formal Semantics of the Mass/Count Distinction

2.1. Two Types of Aggregation

As a core constituent of analyses of the mass/count distinction, it has always been under debate how to represent aggregations that are involved in the semantics of nominals. A nominal in a natural language may denote an aggregation of multiple entities in a situation. For instance, in a scenario where Frege and Russell are the only logicians, sentence (9) can have such a reading that Frege and Russell are the authors of a single paper, whereas the most prominent interpretation of (10) is that Frege wrote a paper and Russell wrote another. Still, sentence (10) could serve as a paraphrase of (9) under another possible interpretation of the latter.

(9) The logicians wrote a paper.

(10) Frege wrote a paper and Russell wrote a paper.

Therefore, the denotation of the plural definite description **the logicians**, in the scenario at issue, should be represented as an aggregation in which the individual components are still grammatically accessible. That is, $[\![$**the logicians**$]\!]$ displays dual properties: the unity of the aggregation and the respective grammatical accessibility of individual components Frege and Russell. This duality is evidenced by the fact that the predicate of (9) can be applied to either the aggregation as a whole (i.e., the logicians collaborate as a group) or to the individuals constituting the aggregation (i.e., the logicians each write a paper).

There have been a number of competing proposals for the representation of aggregations that fall under the denotations of plural nominals, such as *group* (Landman 1989), *set* (Chierchia 1998) and *plurality* (Nicolas 2008). It is not the focus of this article to contribute to this debate on representation of aggregations; instead, what matters is that the representation of denotations of plural nominals displays the formal duality indicated by the semantic ambiguity of sentences such as (9). Particularly, the formal representation should preserve the respective grammatical accessibility of components of an aggregation.

Following Nicolas (2008), I assume that plural noun phrases denote *pluralities*. Formally, Frege $\sqcup$ Russell is the plurality consisting of exactly Frege and Russell. Also, Frege$\sqcup$Russell represents the denotation of the noun phrase **Frege and Russell** where $[\![$**Frege**$]\!] =$ Frege and $[\![$**Russell**$]\!] =$ Russell. More generally, the plurality comprised of a set S of entities is denoted by $\bigsqcup S$. Moreover, 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 with pluralities, *mereological sum* or *fusion* essentially comes with unity but not multiplicity.[2] 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 without visible inner structure, though possibly physically discrete (e.g., a does not overlap with a'). Formally, the unity of $a \oplus a'$ can be formulated as (11), which says that nothing is among a fusion except for the fusion itself.

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

Mereological sums or fusions comprise the denotations of mass noun phrases, as is illustrated by (12) which is seldom, if not never, considered as a well-formed sentence, even if there are multiple portions of water in question.

(12) *The water is connected to each other.

[2] See Champollion and Krifka 2014 for an axiomatic characterization of *sum*.

Although it is also rather controversial what constraints antecedents of reciprocals are subject to, it is generally agreed that the antecedent NP should denote an aggregation of multiple entities that are respectively grammatically accessible. This constraint is also justified by the ungrammaticality of (13) in which the reciprocal has a singular count noun phrase as its antecedent. The ungrammaticality of (12) naturally follows from this constraint if it is assumed that the denotations of mass NPs consist of fusions, in which no proper part is individually visible. Specifically, the denotation of **the water** in (12) is represented as a single entity whose inner structure (e.g., consisting of multiple portions of water) is invisible to the semantic derivation.

(13) *The chair is piled on top of each other.

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.

Two different pluralities 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. As a consequence, mereological sum cannot be used to represent the aggregation formation denoted by conjunction. This can be illustrated by an example, which is similar to the one Landman (1989) uses to illuminate the distinction between sums and groups. If the subject NP of (14a) denotes the sum of the two halves of the water, which is exactly the entire portion of water contained in the glass, it would be expected that (14a) and (14b) entail each other, since the two sentences have semantically equivalent subject NPs. The semantic equivalence is obvious, given the fact that the sum of the left half and the right half of the water is also the entire portion of water in the glass. The mutual entailment between (14a) and (14b) is incompatible with the intuition that one of them can be true without the truth of the other.

(14) a. The upper half of the water and the lower half are separated.
b. The left half of the water and the right half are separated.

Therefore, it is pluralities, rather than mereological sums, that comprise the denotations of plural definite descriptions.

2.2. Mass/Count: A Typal Distinction

Given the assumption that mass NPs and count NPs denote aggregations represented with different operators, it still needs to be answered: what underlies the characteristic properties of the mass/count distinction such as restriction of plural morphology and distribution of determiners? Many of these properties are apparently orthogonal to the distinction regarding representation of aggregations. For instance, the interpretations of neither mass nouns nor singular count nouns could plausibly involve pluralities, whereas only singular count nouns could be pluralized. Moreover, this contrast cannot be ascribed to the difference that the denotations of mass nouns include mereological sums of multiple entities while those of singular count nouns exclusively consist of individuals, i.e., an aggregation/singularity contrast. The infeasibility of such a strategy follows from the notion of mereological sum. Specifically, an individual is the sum of all the parts of itself.

Therefore, it is reasonable to believe that the mass/count distinction is semantically based on contrastive properties in addition to the sum/plurality distinction. A plausible proposal comes from Rothstein 2010, in which it is fundamentally assumed that the mass/count distinction reflects the *typal* distinction of their denotations. Also, the threefold interpretation of noun stems proposed by Chierchia (2010) will be employed to formulate my analysis.

First of all, each noun stem **N** is associated with a *number-neutral* property N (Chierchia 2010). N is number-neutral, in the sense that it can contain both atomic **N**s (if there are) and sums of N-atoms. Specifically, N comes with a threefold interpretation:

(i) a positive extension N_+ containing entities that definitely have the property of being N;

(ii) a negative extension N_- consisting of entities that are definitely not N;

(iii) a vagueness band $N_?$ of entities falling under neither N_+ nor N_-.

As an illustration, if a chair is cut bit by bit, there will come a point where it is no longer certain whether the remainder is still a chair. Formally, the remainder at that point falls under the vagueness band $\text{CHAIR}_?$.

The denotation of a mass noun $\mathbf{N}_{\mathbf{mass}}$ is identical to the positive extension of the associated number-neutral property.

(15) $[\![\mathbf{N}_{\mathbf{mass}}]\!] = N_+$

In contrast, the denotation of a count noun $\mathbf{N}_{\mathbf{count}}$ consists of *count atoms* (Rothstein 2010: 363) that are of the form $\langle d, c\rangle$ where $d \in N_+$ and c is the context of the discourse.

(16) $[\![\mathbf{N}_{\textbf{count}}]\!] = \{\langle d, c\rangle : d \in N_{\text{AT}}\}$

N_{AT} is the subset of N_+ that contains exactly the N-atoms. Different from Rothstein's (2010) definition, pluralization of count nouns is formulated in terms of plurality formation rather than in terms of mereological sums.

(17) $\text{PL}([\![\mathbf{N}]\!]) = \begin{cases} \{\bigsqcup S : \emptyset \subsetneq S \subseteq [\![\mathbf{N}]\!]\} & \text{if } [\![\mathbf{N}]\!] \subseteq D \times \{c\} \\ \text{undefined} & \text{otherwise} \end{cases}$

The context index can serve a variety of purposes. For instance, the exact division between the three divisions of each number-neutral N is dependent on the particular c (Chierchia 2010: 117). Specifically, it varies across contexts where the borderline between N_+ and $N_?$ is. In the case of chair cutting, it is usually infeasible to provide a uniform criterion to precisely distinguish N_+-elements from those contained in $N_?$. In the framework of Rothstein 2010, context also plays the role of type marker. As is represented by (15) and (16), assume that D is the domain for the interpretation of number-neutral properties associated with noun stems, each $\mathbf{N}_{\textbf{mass}}$ is a subset of D that is directly adopted from the positive extension N_+; whereas $\mathbf{N}_{\textbf{count}} \subseteq D \times \{c\}$. The typal distinction is mainly employed to account for various characteristic properties of the mass/count distinction, such as restriction of plural morphology to singular count nouns and distribution of determiners (Rothstein 2010). Such a strategy could be instantiated by (17).

Despite the assumption of a typal distinction underlying the mass/count distinction, it is still necessary to have two types of representation of aggregations. However, it is not the focus of this article to argue against Rothstein's (2010) analysis in which various properties of the mass/count distinction is explained in terms of the mere typal distinction.[3]

To sum up, the mass/count distinction displays a large variety of properties that point toward both multiple representations of aggregations and a typal difference between mass nouns and count nouns. Particularly, the former concerns the grammatical (in)accessibility of components of aggregations, as is evidenced by the presence/absence of a distributive reading and the grammaticality of reciprocal constructions.

3. Against the Universal Grinder

As has been noted, transformation between mass nouns and count nouns occurs from time to time. Such transformation usually comes with constraints on the context. For instance, an utterance of (6a) (repeated below as (18)) is felicitous and grammatical only if it is clear in the context what

[3]For such an argument based on the semantics of reciprocals, see Cai 2016.

counts as *a water*. In a restaurant or a bar, **a water** usually denotes a portion of water that is contained in a glass which has a uniform shape and volume.

(18) Can I have a water?

This instantiates the count form of a predominantly mass noun. As for the opposite direction, which is instantiated by (8) (repeated below as (19)), Pelletier (1975) proposes the well-known *universal grinder* (20), based on the observation that (19) is infelicitous if there are only whole bicycles on the floor that are not disassembled.

(19) There is bicycle all over the floor.

(20) "Take an object corresponding to any (apparent) count noun he wishes (e.g., 'man'), put the object in one end of the grinder and ask what is on the floor (answer: There is man all over the floor). . . . this test can be employed at will, always giving us a mass sense of count nouns having physical objects as their extension." (Pelletier 1975: 456)

The grinding proposal is widely interpreted as saying that the mass form $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ only denotes fragments of or stuff made from individuals falling under $[\![\mathbf{N}_{\mathbf{count}}]\!]$, while atomic **N**s are precluded from the denotation of the mass form (Cheng et al. 2008, Rothstein 2010). A possible version of formalization is as (21).

(21) $[\![[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}]\!] = \{x : \exists y[y \in N_{\mathrm{AT}} \wedge x < y]\}$

In other words, the core of the grinding approach is the semantically encoded *natural atomlessness*, in the sense that only fragments of atoms, but not whole atoms, are allowed for, which appears to capture the intuition about mass forms of predominantly count nouns. In addition, the grinder is claimed to be *universal*. That is, it should be applicable to any count nouns.

However, neither the universality nor the natural atomlessness is tenable if more data are scrutinized. For instance, the grinder apparently does not apply to group nouns such as **family**, **team** and **legion**. Specifically, a situation can hardly be found in which it is felicitous to utter (22).

(22) *There is team all over the floor.

It is widely agreed that the denotations of group nouns are composed of composite atomic objects, which are often named *groups* (Chierchia 1998, Rothstein 2010). For instance, a football team by

default is formed by multiple players who act as a unit in games. Despite the preservation of grammatical accessibility of components contained in a group (as is evidenced by the grammaticality of (23)), groups are also atoms and can serve as units of grammatical counting, such as **two families**. Therefore, group nouns can be employed to talk about multiple entities as a countable unit or atom.

(23) The family is supporting each other.

Hence, the ill-formedness of sentence (22) could be understood as a consequence of two contradictory operations. The first one is generating a composite atom (i.e., a team) out of the components (i.e., the individual members of the team) by using the group noun **team**. This operation could be considered as *atom generating*, which is incompatible with the co-occurring operation of *deatomization* via conversion of the group noun **team** into its mass form. The atom generating operation indicates that the speaker intends to refer to the team as a unit, whereas the deatomization operation displays the speaker's intention of talking about the aggregation of team members as being atomless. As could be expected, the two operations conflict with each other.

What is more problematic with the grinder approach is its strict exclusion of atomic entities from $[\![[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}]\!]$. If it is really the case that atomic entities are excluded from the semantics of mass forms of predominantly count nouns, it would be uniformly bad to denote aggregations of N-atoms by $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$. However, some informants think that it is not totally bad to use (24) to describe a pile of thousands of whole bananas. In addition, this is also the case for other names of fruits and vegetables (e.g., **strawberry**, **tomato**). In contrast, such partial felicity is not available to names of artifacts (19).

(24) The tower is made of banana.

In order to verify this contrast, a small survey was conducted on Ibex Farm with 99 native English speakers (based on self-identification) recruited via Mechanical Turk. Basically, the participants were instructed to evaluate the appropriateness of using the following sentences to describe the objects in question on a 5-point scale (with 1 point standing for *definitely inappropriate* while 5 for *definitely appropriate*). Each participant is randomly assigned one of the sentence-object pairs.

(25) Sentence: The tower is made of chair.
Object: A tower exclusively consisting of hundreds of whole chairs

(26) Sentence: The tower is made of banana.
Object: A tower exclusively consisting of thousands of whole bananas

(27) Sentence: The pile is made of rock.
Object: A pile of rocks

The results of Wilcoxon Rank Sum test ($W = 1138$, $p = .0178$) shows that the usage (26) ($N = 49$, $M = 3.59$, $SD = 1.29$) is noticeably more felicitous than that of (25) ($N = 36$, $M = 2.92$, $SD = 1.36$). Such a variation of felicity across nouns is unexpected if (21) properly represents the semantics of mass forms of predominantly count nouns, as the definition in itself does not allow for different degrees of violations given the fact that the objects in question, the chair tower and the banana tower, are both exclusively formed by atomic objects. The grinder metaphor cannot save the situation, either. There is no reason why whole bananas are more likely to survive the grinding operation and enter into the semantics of the mass form than are whole chairs.

What is probably even more surprising is the result concerning (27) ($N = 14$, $M = 3.93$, $SD = 1.14$), which fails to show that such usage of $\textbf{rock}_{\textbf{mass}}$ is more felicitous than $\textbf{banana}_{\textbf{mass}}$ in (26). However, as a grammatically flexible noun, **rock** has both a count form and a mass form by default. Particularly, there is nothing that prevents $\textbf{rock}_{\textbf{mass}}$ from containing ROCK-atoms in its extension. Take (28) as an example. It is clear that the material of which the Earth's outer solid layer is made does not exclude those pieces of rock which can count as *rocks*.

(28) The Earth's outer solid layer is made of rock.

Formally, (sums of) ROCK-atoms also fall under $[\![\textbf{rock}_{\textbf{mass}}]\!]$, though they are not represented as count atoms of the form $\langle d, c\rangle$. Therefore, it is confusing to see the imperfect felicity of (27). Although this partial felicity does not directly constitute evidence against the grinder approach, it is argued to be in support of my analysis in Section 4.

In this section, preliminary empirical evidence has been presented which casts doubt on the soundness of the grinder proposal. Specifically, it is problematic to impose the constraint of natural atomlessness on the denotation of $[\mathbf{N}_{\textbf{count}}]_{\textbf{mass}}$. Furthermore, such a constraint seems to conflict with the general observation that the mass/count distinction concerns the way nominals refer, rather than the structures of the things they refer to.

4. The Uniformity of Mass Nouns

4.1. Formal Atomlessness

Despite the fact that it is probably infeasible to incorporate natural atomlessness into the semantics of $[\mathbf{N}_{\textbf{count}}]_{\textbf{mass}}$, it is true that $[\mathbf{N}_{\textbf{count}}]_{\textbf{mass}}$ is seldom used to denote aggregations of N-atoms, though partial felicity is possible (26). Therefore, it remains crucial to account for this phenomenon which has led to existing theories appealing to natural atomlessness on the semantic level. In this section, it is argued that a plausible account could be formulated in terms of the distinction of aggregation representation. That is, mereological sum vs. plurality.

As is observed in the survey, the imperfectness of (27) indicates that the inclusion of N-atoms in

the denotation of a mass noun $\mathbf{N}_{\mathbf{mass}}$ does not guarantee the felicity of denoting aggregations of N-atoms by $\mathbf{N}_{\mathbf{mass}}$. Together with the contrast between (25) and (26), this surprising phenomenon points toward, though does not entail, an origin of preference for natural atomlessness of denotations other than semantically encoded natural atomlessness.

Before looking for an exotic factor that could underlie the appropriateness judgments, it is helpful to search for potential origins within the framework adopted here. As is introduced in Section 2, two pairs of contrastive formal representations underlie the mass/count distinction and the semantics of nominals in general. One pair, sum vs. plurality, concerns representation of aggregations; while the other regards the typal difference between the denotations of mass nouns (uncountable entities from the domain D) and those of count nouns (i.e., count atoms of the form $\langle d, c\rangle \in D \times \{c\}$).

First of all, the second pair does not seem to have special effect on the mass forms $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ of predominantly count nouns $\mathbf{N}_{\mathbf{count}}$ except that $[\![[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}]\!]$ contains no count atoms. Particularly, the typal difference is not accountable for the infelicity of $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ denoting aggregations of N-atoms. For instance, there is such a subcategory of mass nouns, namely, *atomic mass nouns*, which denote entities with salient atomic structures, such as **furniture** and **equipment**. There are two equivalent ways to formulate the definition of $[\![\mathbf{furniture}]\!]$.

(29) a. $[\![\mathbf{furniture}]\!] = \text{FURNITURE}_{+}$
b. $[\![\mathbf{furniture}]\!] = \{\bigoplus S : \emptyset \subsetneq S \subseteq \text{FURNITURE}_{\text{AT}}\}$

The equivalence of (29a) and (29b) follows from the fact that only (aggregations of) individual pieces of furniture (i.e., FURNITURE-atoms), but not fragments of furniture, can be counted as furniture with certainty. That is, **furniture** normally denotes (aggregations of) FURNITURE-atoms rather than furniture fragments, though $[\![\mathbf{furniture}]\!]$ does not contain count atoms. Thus, the absence of count atoms cannot explain the infelicity of denoting aggregations of N-atoms by $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$.

In addition to the absence of count atoms, pluralities are excluded from $[\![[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}]\!]$. As an illustration, sentence (30) is ungrammatical even if the speaker is pointing at a pile of fragments of multiple bicycles.

(30) *The bicycle is piled on top of each other.

It follows that the aggregations contained in $[\![[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}]\!]$, if there are, are represented as mereological sums instead of pluralities. Nonetheless, it remains unsettled exactly what constitutes the denotation of $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$. It has been shown that it is infeasible to exclude N-atoms from

$[\![[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}]\!]$. Also, proper parts of N-atoms should be included, since $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ is most likely to denote N-fragments. Therefore, definition (31) is an plausible candidate.

(31) $[\![[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}]\!] = \{d : d \leq \bigoplus N_{\text{AT}}\}$

Given (31), it will be expected that $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ can denote N-atoms, N-fragments and their mixture. Thus, it has to be clarified what gives rise to the preference for N-fragments over N-atoms when $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$ is being used, as this asymmetry is not literally encoded in definition (31). Considering that natural atomlessness cannot be part of the semantics of $[\mathbf{N}_{\mathbf{count}}]_{\mathbf{mass}}$, it is most probable to find the origin of favoring N-fragments over N-atoms in pragmatics.

Recall that even the grammatically flexible noun **rock**, when occurring in its mass form without classifiers, cannot serve as a *perfect* description of a pile of rocks, despite the fact that (sums of) ROCK-atoms also fall under $[\![\mathbf{rock}_{\mathbf{mass}}]\!]$. What may well be confusing is the perfect felicity of (28), given the fact that rocks (i.e., ROCK-atoms) also form part of the material of which the Earth's outer solid layer is made. This contrast of felicity naturally draws attention to the difference between the Earth's outer solid layer and the pile of rocks. Despite the fact that both contain rocks, the former is so great in size that it could be perceived as being a coherent body without salient atomic structure; whereas the pile of rocks, given the description in (27) **a pile of rocks**, is most likely to be imagined as a pile of rocks with readily visible individual components. Following the general semantics of the mass/count distinction introduced in Section 2, the interpretation of the two forms of **rock** could be formulated as (32).

(32) a. $[\![\mathbf{rock}_{\mathbf{mass}}]\!] = \text{ROCK}_{+}$
b. $[\![\mathbf{rock}_{\mathbf{count}}]\!] = \{\langle d, c\rangle : d \in \text{ROCK}_{\text{AT}}\}$
c. $[\![\mathbf{rocks}]\!] = \{\bigsqcup S : \emptyset \subsetneq S \subseteq [\![\mathbf{rock}_{\mathbf{count}}]\!]\}$

The elements of $[\![\mathbf{rocks}]\!]$ are pluralities consisting of count atoms that are grammatically accessible. In contrast, each element of $[\![\mathbf{rock}_{\mathbf{mass}}]\!]$ is a mereological sum, in which no atomic elements are grammatically accessible. The inaccessibility of atoms is evidenced by the ungrammaticality of taking $\mathbf{rock}_{\mathbf{mass}}$ as the antecedent of a reciprocal (33).

(33) *(The) Rock is piled on top of each other.

Formally, the inaccessibility of atoms and thus the unity of a mereological sum are enforced by the fact that mereological part-of relation holds not only between an atom and a sum of atoms (e.g., between a chair and a sum of multiple chairs) but also between a fragment of an atom and the sum of atoms (e.g., between a chair leg and the sum of multiple chairs). In other words, the mereological

part-of relation cannot distinguish atoms from fragments of atoms if both are contained in a sum. As a consequence, the atoms constituting a sum are not 'visible' in the semantic representation. Therefore, each mereological sum is *formally* atomless.

Specifically, a pile of ROCK-atoms, as an element of $[\![\textbf{rock}_{\textbf{mass}}]\!]$, is represented as an atomless and thus coherent body, despite the existence of individual rocks. Still, the mere formal atomlessness inherent to a mereological sum cannot account for the imperfectness of (27), since aggregations of FURNITURE-atoms are also represented as sums in $[\![\textbf{furniture}]\!]$ but it is perfectly felicitous and grammatical to denote an aggregation of multiple pieces of furniture by **(the) furniture**.

A salient contrast between the two names, $\textbf{rock}_{\textbf{mass}}$ and **furniture**, is that the former by default also has a count form $\textbf{rock}_{\textbf{count}}$, which refers to aggregations of ROCK-atoms as pluralities (32b, 32c) with individual rocks being grammatically accessible. Thus, the usage of $\textbf{rock}_{\textbf{mass}}$ in (27) could trigger the implicature that what is denoted is perceived as an atomless and coherent body (as the mass form, rather than the alternative count form, is used), which is at odds with the salient atomic structure of the pile of rocks. Hence, it is not unexpected that (27) is not perfectly felicitous.

The same logic also applies to (25) and mass usage of predominantly count nouns in general. Given the existence of the default count form of **chair**, usage of the mass form $\textbf{chair}_{\textbf{mass}}$ gives rise to the implicature that what is described (i.e., the chair tower) is perceived as and therefore referred to as an atomless and coherent body. However, the object is a tower composed of hundreds of chairs, which is far from being atomless. In contrast, an utterance of (19) is felicitous if what is on the floor is (completely) decomposed bicycles. That is, the BICYCLE-atoms are no longer perceivable, or at least, far from being salient.

Overall, grinding (i.e., natural atomlessness) is probably the most usual force driving the usage of the mass form of a predominantly count noun. Otherwise, the default count form would have been used. In other words, fragments of N-atoms, which cannot be counted as N-atoms and thus cannot be denoted by $\textbf{N}_{\textbf{count}}$, but which stand in a close relation to the later and fall under the denotation of $[\textbf{N}_{\textbf{count}}]_{\textbf{mass}}$, is the most likely trigger of the usage of $[\textbf{N}_{\textbf{count}}]_{\textbf{mass}}$.

Nonetheless, it is observed that the use of the mass forms of **banana** and other names of fruits and vegetables is less problematic even if what is described is an aggregation of atomic objects. The question could be formulated as: what makes people more willing to refer to a large aggregation of bananas as an atomless and coherent body? Given the definition (31) in terms of formal atomlessness, the answer could be obtained by examining the difference in the perception of the chair tower vs. the banana tower.

4.2. Homogeneity: From Referents to Expressions

As is argued in Section 4.1, the infelicity of (25) is resulted from the mismatch between (i) the formally atomless representation encoded in **chair**$_{\textbf{mass}}$ and (ii) the salient atomic structure of the chair tower, given the availability of the alternative count form **chair**$_{\textbf{count}}$. That is, the chairs forming the tower are salient atomic components of the construction. This tension is also inevitable with respect to the banana tower exclusively composed of whole bananas (26), which nonetheless appears to be significantly more felicitous.

First, there is no motivation to assume a different semantics for **banana**$_{\textbf{mass}}$ than (31) to undermine the tension. Thus, the contrast in felicity is most likely to be a consequence of the difference between the perception of the two objects. Specifically, it needs to be explained why it is less problematic to perceive and thus represent the banana tower as an atomless and coherent body. This issue could be alternatively formulated as: why each whole banana is less salient as an atom of the banana tower?

The absence of a significant contrast in acceptability between (26) and (27) provides a clue. Although both **chair** and **banana** are predominantly count nouns whereas **rock** is a flexible noun, the results regarding (25), (26) and (27) indicate that bananas are more similar to rocks than to chairs in some aspect that notably influences people's perception of aggregations. One prominent distinction between chairs and rocks is that chairs are *indivisible*, while rocks are not. Formally, I define indivisibility with respect to number-neutral property N: $d \in N_+$ is indivisible iff

(34) for any two non-overlapping entities a and b such that $a, b < d$, it holds that $a \in N_-$ or $b \in N_-$ (Cai 2015)

By this definition (34), a chair is indivisible because any way of dividing a chair will produce at least one proper part that is definitely not a chair. In contrast, rocks are generally *homogeneous* in the sense that a rock can be divided into multiple fragments all of which fall under ROCK$_+$, even if not all of them could be counted as *a rock*. Formally, $d \in N_{\text{AT}}$ is homogeneous iff

(35) there are two non-overlapping $a, b \in N_+$ such that $a \oplus b = d$

There are several points which are noteworthy and which in themselves should be discussed in detail if without limit of length. Firstly, ROCK$_{\text{AT}} \subsetneq$ ROCK$_+$ and the inequality between ROCK$_+$ and ROCK$_{\text{AT}}$ is justified by the fact that **rock**$_{\textbf{mass}}$ denotes a mineral matter with variable composition and **a rock** denotes a piece of such mineral matter which is subject to (vague) constraints on shape and size. Secondly, definition (35) cannot serve as a criterion for homogeneity in general, as sums of atomic objects also satisfy this description. For instance, the sum of multiple chairs

could be divided into two sub-aggregations both of which are contained in CHAIR_+. Rather, definition (35) characterizes the homogeneity of entities with atomic structures in terms of divisibility of atoms. Recall that the notion of homogeneity defined in (35) comes with the constraint that $d \in N_{\text{AT}}$. Although this definition may not be as general as expected, it succeeds in characterizing the homogeneous atomic objects denoted by flexible nouns in contrast with the indivisibility of atoms denoted by predominantly count nouns such as **chair** and **bicycle**. Furthermore, homogeneity does not mean infinite divisibility. As has been widely noted, if a rock is repeatedly divided, there will come a point where the remainder is no longer an element of ROCK_+.

As for names of fruits and vegetables, it might be expected that they are on a par with other predominantly count nouns such as **chair** regarding indivisibility. However, many informants think (36) is an appropriate (though probably imperfect) description of a box containing only halves of bananas each of which is obtained from a different banana.

(36) There are bananas in the box.

However, a half of a banana is *not definitely* a banana. If people are asked to pick out a banana from a box containing a whole banana and a half, the whole banana will be most likely to be selected. Hence, half a banana is most likely to fall under the vagueness band $\text{BANANA}_?$ rather than the positive extension BANANA_+. As a consequence, bananas are neither indivisible nor strictly homogeneous. In other words, they appear to be *weakly homogeneous*. Intuitively, at least two aspects underlie the contrast between bananas and chairs. *Structurally*, cars and bicycles have fine-grained and salient inner structures, whereas a banana can be roughly perceived as a coherent body made of 'banana stuff' without salient inner structures. *Functionally*, a car cannot be divided into multiple parts all of which can function as cars, while half a banana is also edible and provides the same nutrients as do whole bananas.

Given the weak homogeneity of BANANA-atoms, each of them could be approximately perceived as a portion of banana stuff. Therefore, the banana tower could be roughly perceived as a large portion of banana stuff and its representation could (imperfectly) be formally atomless, which is encoded in $\textbf{banana}_{\textbf{mass}}$. That is, the (weak) homogeneity significantly undermines the tension between the natural atomicity of bananas and the formally atomless representation (31) of the aggregation of bananas.

Nonetheless, the homogeneity formulated as (35) does not guarantee grammaticality and felicity of using mass forms of predominantly count noun phrases. For instance, a bar of chocolate could be divided into two fragments both of which also fall under the denotation of **bar of chocolate**, whereas (37) is still ill-formed.[4]

[4]Thanks to a reviewer for drawing my attention to such examples.

(37) *The tower is made of bar of chocolate.

An account analogous to that of the ungrammaticality of mass forms of group nouns applies to (37). The classifier **bar** serves as an atom generator that extracts atomic entities out of the denotation of **chocolate**$_{\textbf{mass}}$. The application of this classifier indicates that the chocolate is being referred to as an atomic entity. However, the mass form of **bar of chocolate** refers to the chocolate as being formally atomless. Therefore, two incompatible operations are applied to **chocolate**$_{\textbf{mass}}$, which leads to the ill-formedness of (37).

To sum up, it is formal atomlessness (rather than natural atomlessness) that is encoded in the mass forms of predominantly count nouns. Given the availability of the default count form, usage of the mass form implicates that the referent is perceived as atomless, which in turn triggers the implicature that the referent does not include atoms (i.e., naturally atomless). However, the second step of implicating is weakened when the atomic elements comprising the referent are (weakly) homogeneous. That is, the (weak) homogeneity of atomic components enables people to perceive the aggregation as a coherent body. As a consequence, the grinding implicature is significantly undermined, as is illustrated by (26).

Such a grinding implicature is also available to grammatically flexible nouns such as **rock**, which is instantiated by the imperfectness of (27). However, there is still a distinction between flexible nouns and predominantly count nouns. The former have both a count form and a mass form by default, whereas the mass form of the latter is *marked*. For instance, sentence (28) is felicitous despite the fact that the outer solid layer of the Earth contains numerous pieces of rock that could be counted as *rocks* (i.e., ROCK-atoms). This phenomenon is actually in line with the analysis based on formal atomlessness. The rocks, when being viewed as part of the outer solid layer of the Earth, are so tiny that the whole outer solid layer could be perceived as an atomless and coherent body and be denoted by **rock**$_{\textbf{mass}}$. In contrast, the mass form of a predominantly count noun is *marked*. As a consequence, usage of $[\mathbf{N}_{\textbf{count}}]_{\textbf{mass}}$ will not be perfectly felicitous as long as the predominant count form $\mathbf{N}_{\textbf{count}}$ is applicable. Therefore, even if the surface of the Earth is entirely covered with bananas, an utterance of (38a) is not perfect, while (38b) is still a better way to describe the Earth.

(38) a. The Earth is covered with banana.
b. The Earth is covered with bananas.

Hence, the usage of $[\mathbf{N}_{\textbf{count}}]_{\textbf{mass}}$ is most felicitous when the referent can no longer be denoted by $\mathbf{N}_{\textbf{count}}$. Such a situation occurs when the atomic structure of the referent is lost, for example, when the atomic objects are ground. Nevertheless, this does not justify the proposal of encoding natural atomlessness into the semantics of $[\mathbf{N}_{\textbf{count}}]_{\textbf{mass}}$, since N-atoms are not strictly excluded from $[\mathbf{N}_{\textbf{count}}]_{\textbf{mass}}$, as is illustrated by the significant contrast between (25) and (26). Rather, grinding (i.e.,

natural atomlessness) is an implicature triggered by the formally atomless representation (31) and the availability of the unmarked count form $\mathbf{N}_{\mathbf{count}}$.

Moreover, such an analysis is in accordance with the general observation that the mass/count distinction concerns the way nominals refer, rather than the structures of the things they refer to.

5. Conclusion

The contrast between mereological sum and plurality underlies a variety of semantic properties of nominals, including those concerning the mass/count distinction. The inherent unity and formal atomlessness that come with mereological sum account for the tendency of mass forms of predominantly count nouns to denote fragments of atomic objects. The universal grinder appears to capture such tendency, but it oversimplifies the image of massification of count nouns and thus fails to account for the variation illustrated by (25) and (26). Instead, it is formal atomlessness that triggers the implicature of natural atomlessness, which is sensitive to the indivisibility and homogeneity of referents. In order to thoroughly examine this analysis, more types of nominals need to be tested apart from names of artifacts, fruits and vegetables.

References

Barner, D. and J. Snedeker (2005). Quantity judgments and individuation: Evidence that mass nouns count. *Cognition 97*, 41–66.

Cai, H. (2015). A vagueness approach to the mass/count distinction. *University of Pennsylvania Working Papers in Linguistics 21*, 6.

Cai, H. (2016). Atomic mass nouns: Unity, plurality and semantic flexibility. In *Studies in the Linguistic Sciences: Illinois Working Papers*.

Champollion, L. and M. Krifka (2014). Mereology. In *Cambridge Handbook of Semantics*. http://ling.auf.net/lingbuzz/002099: Cambridge University Press.

Cheng, L. L., J. Doetjes, and R. Sybesma (2008). How universal is the universal grinder? *Linguistics in the Netherlands 25*, 50–62.

Chierchia, G. (1998). Plurality of mass nouns and the notion of "semantic parameter". In *Events and Grammar*. Dordrecht: Kluwer.

Chierchia, G. (2010). Mass nouns, vagueness and semantic variation. *Synthese 174*, 99–149.

Landman, F. (1989). Groups, I. *Linguistics and Philosophy 12*, 559–605.

Nicolas, D. (2008). Mass nouns and plural logic. *Linguistics and Philosophy 31*, 211–244.

Pelletier, F. J. (1975). Non-singular reference: Some preliminaries. *Philosophia 5*, 451–465.

Pelletier, F. J. and L. K. Schubert (1989). Mass expressions. In *Handbook of philosophical logic*, pp. 327–407. Springer Netherlands.

Rothstein, S. (2010). Counting and the mass/count distinction. *Journal of Semantics 27*, 343–397.