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Fred Landman
Tel Aviv University, Israel

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FRED LANDMAN
Tel Aviv University

ICEBERG SEMANTICS FOR COUNT NOUNS AND MASS NOUNS: CLASSIFIERS, MEASURES AND PORTIONS

ABSTRACT: The background for this paper is the framework of Boolean semantics for mass and count nouns, and singular and plural count nouns, as developed from the work of Godehard Link in Link (1983) (see e.g. the expositions in Landman 1991, 2010).

Link-style Boolean semantics for nouns (here called *Mountain semantics*) analyzes the oppositions *mass-count* and *singular-plural* in terms of the notion of *atomicity*: counting is in terms of singular objects, which are taken to be atoms. Consequently, Link bases his semantics on two separate Boolean domains: a non-atomic mass domain and an atomic count domain. Singular count nouns are interpreted as sets of atoms, and semantic plurality is closure under sum, so plural objects are sums of atoms.

In this, sorted setup portions - like *two portions of soup* - are a puzzle: they are mass stuff - *soup* -, but count - *two*. But in order to be count they must be atoms. But they are not, because they are just soup. Mountain semantics can deal with portions, but at a cost.

In the first part of this paper I outline *Iceberg semantics*, an alternative to Mountain semantics within the general framework of Boolean semantics.

Iceberg semantics specifies a compositional mechanism which associates with the standard denotation of any noun phrase (here

called the *body*) a *base* set, a set that generates the body under the sum operation $\sqcup$. For count nouns, the base is the set in terms of which the members of the body are counted and to which distribution takes place. In Iceberg semantics, what allows counting to be correct is the requirement on the interpretations of count nouns that the base of their interpretation is (contextually) *disjoint*.

Already at *this* level we see two salient properties of Iceberg semantics:

- Atoms and atomicity play no role in the theory, so we can assume an unsorted interpretation domain for mass nouns and count nouns. In Iceberg semantics, *mass* and *count* can be seen as different perspectives on the same stuff (different bases for the same body). This means that we can do away with the extreme body-sorting and body-gridding that atomicity entails. With this we allow a simpler and more elegant analysis of mass-count interactions. For instance, portions can just be 'mass' stuff, evaluated relative to a count base.
- The mass-count distinction is formulated in terms of disjointness of the base. Iceberg semantics associates bases not just with the interpretations of lexical nouns, but with NPs in general and with DPs. This means that Iceberg semantics provides a compositional semantic theory of the mass-count distinction, and hence it provides a framework in which the mass-count nature of complex NPs and of DPs can be fruitfully studied.

It is the analysis of complex NPs and their mass-count properties that is the focus of the second part of this paper. There I develop an analysis of English and Dutch pseudo- partitives, in particular, measure phrases like *three **liters** of wine* and classifier phrases like *three **glasses** of wine*. We will study measure interpretations and classifier interpretations of measures and classifiers, and different types of classifier interpretations: container interpretations, contents interpretations, and - indeed - portion interpretations. Rothstein (2011) argues that classifier interpretations (including portion interpretations) of pseudo partitives pattern with count nouns, but that measure interpretations pattern with mass nouns. I will show that this distinction follows from the very basic architecture of Iceberg semantics.

1. ICEBERG SEMANTICS

1.1. Boolean background

I presuppose familiarity with elementary concepts for Boolean algebras, but give here, for ease of reference and notation, the concepts that play a central role in this paper.

Interpretation domain:
The semantic interpretation domain is a complete Boolean algebra **B** with operations of complete join $\sqcup$ and complete meet $\sqcap$ (operations mapping subsets of B into B).

Boolean part set: (Small letters: elements of B; Capitals: subsets of B.)
$\mathbf{(}x\mathbf{]} = \{b \in B: b \sqsubseteq x\}$ The set of all Boolean parts of x
$\mathbf{(}X\mathbf{]} = \mathbf{(}\sqcup X\mathbf{]}$ The set of all Boolean parts of X

Closure under $\sqcup$
$*X = \{b \in B: \exists Y \subseteq X: b = \sqcup Y\}$ The set of all sums of elements of X.
X generates Z under $\sqcup$ iff $Z \subseteq *X$ X generates Z under $\sqcup$ if all elements of Z are sums of elements of X.

Minimal elements and atoms:
$\mathbf{min}(X) = \{x \in X: \forall y \in X: \text{if } y \subseteq x \text{ then } y{=}x\}$ The set of X-minimal elements.
ATOM $= \mathbf{min}(B - \{0\})$ The set of $B - \{0\}$-minimal elements.

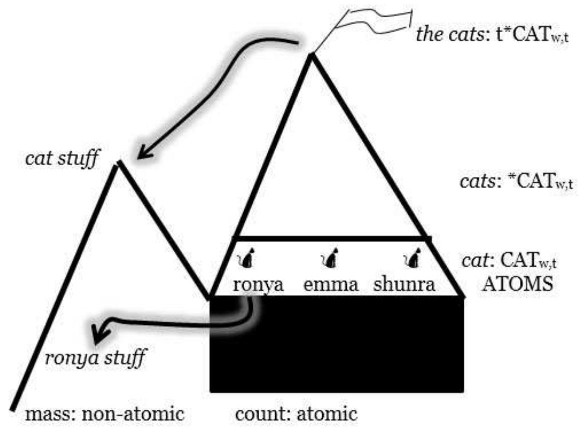
In Link's count domain, ATOM is a subset of B that generates B.

Central for the present paper are the notions of disjointness and overlap:

Disjointness and overlap:
x and y *overlap* iff $x \sqcap y \neq 0$, otherwise x and y are *disjoint***.**
x and y overlap if they have a non-null part in common.
X *overlaps* iff for some $x, y \in X$: x and y overlap, otherwise X is *disjoint***.**
X overlaps if some of its elements overlap.

1.2. Mountain semantics

I call Link-style Boolean semantics *Mountain semantics*, because the semantics of count nouns is grounded in the bottom of the count domain: the singular noun *cat* denotes at index w,t a set of atoms $CAT_{w,t}$, say, {ronya, emma, shunra}; the plural noun *cats* denotes the closure of this under sum: $*CAT_{w,t}$, which is a mountain rising up from the denotation of the singular noun. Since the individual cats are atoms, the relation to their mass parts is indirect:



The set of atoms and the notion of atomicity play a pivotal role in the approach to the mass-count distinction of Mountain semantics. Count noun denotations are distinguished from mass noun denotations in that the elements in a count noun denotation can be *counted*, and allow *distribution*. These notions are defined in terms of *atoms* in Mountain semantics, and their correctness relies on a central property of sets of atoms in complete Boolean algebras:

Counting in terms of atoms: Plurality x in the denotation of *cats* counts as *three cats* iff
x has three *atomic* parts (provably, these are in the denotation of *cat*).
Distribution in terms of atoms: *each of the cats* means: each of the

atomic parts of the sum
of the cats (again, provably, these are in the denotation of *cat*).

Correctness of counting:
If A ⊆ ATOM then *A itself has the structure of a complete atomic Boolean algebra with A as its set of atoms.

This property allows correct counting: every element in the count domain has a unique count, and no elements are skipped over. Thus, if you are a sum of three cats, you provably have as parts one sum of three cats (yourself), three sums of two cats, three single cats and the null object.

A less attractive side-effect is that you don't have any other parts. Mountain semantics is forced into sorted domains with independent part-of relations. This means that there is basically no relation between the part-of order on the Boolean domain and intuitive lexical part-of relations: since Ronya is a (singular) cat, she is an atom in B; since her left front leg is a (singular) leg, it is an atom in B; and since her left front paw is a paw, it too is an atom in B. Thus these objects do not stand in a part-of relation that is internal to the Boolean theory. Similarly, the relation between objects and the mass stuff making them up is not internal: the stuff making up Ronya is not part of Ronya, since Ronya is an atom.

I accepted these conclusions cheerfully in Landman (1989, 1991). But already in Landman (1991) I argued that this means that we must distinguish as distinct many 'flavors' of the same objects (like a mass version of a plural object, a sum version, a group version, etc.) and rely heavily on shifting between domains. The sorting problem is brought out sharply by the *Problem of Portions*. Portions are, what we could call, *countable mass*. Look at the examples in (1):

(1) a. The *coffee* in the pot and the *coffee* in the cup *were each spiked with strychnine*.
b. I drank *two cups of coffee*. I didn't ingest the cups, so I drank *two portions of coffee*.

(1a), a variant of an example in Landman (1991), shows that we can distribute with *each* to *two* items: *the coffee in the pot* and *the coffee in the cup*. Such distribution is indicative for *count* interpretations. The problem is that *coffee* is a mass noun, and hence its denotation is uncountable stuff. And coffee plus coffee is more coffee, more uncountable stuff. But then, how can we distribute in (1a)? Similarly in (1b), where we count two portions of coffee. Intuitively, a portion of coffee is coffee. And coffee plus coffee is more coffee. So how can we count *two* portions of coffee in (1b) if we only have stuff?

In Landman (1991) I proposed, for examples like (1a), an operation that shifts mass objects to atoms in the count domain. This shifts makes mass entities countable. But that does mean that we are going to have in our domains distinct objects: Ronya (count), the stuff making up Ronya (mass), the latter mass stuff as a *portion* of cat stuff (count),. . . And it doesn't stop here.

I am not going to argue that this is a wrong approach (it can be made coherent, if complex). But it *does* seem a bit as if we are shoehorning portions into out sorted structures solely for the sake of atomicity: if we had a working theory in which counting doesn't depend on atomicity, we could hope to accept portions as both mass and countable. Welcome to *Iceberg semantics*.

1.3. Iceberg semantics

In Iceberg semantics nouns are interpreted as icebergs: they consist of a *body* and a *base* and the body is *grounded* in the base. For count nouns, the body looks just like what we assumed in Mountain semantics: the body of the Iceberg interpretation of plural noun *cats* is the closure under sum $*CAT_{wt}$ of the base of its interpretation $CAT_{w,t}$, which is also the body (and base) of the interpretation of singular noun *cat*. So plural nouns are mountains rising up from bases. But the base is not a set of atoms, the elements of the base have parts *within* the Boolean domain B, so the base is, so to say, lifted from the bottom, and it floats.

This means, then, that the notion of singularity is loosened from the notion of atomicity. In fact, both the mass-count distinction and the singular-plural distinction will be defined for icebergs in relation to their base. This means that *the same body* will be mass or count depending on the base it is grounded in. It will also mean that *the same body* will be singular or plural depending on the base it is grounded in. The base forms a perspective on the body, the body itself is *unsorted*.

If we get rid of atomicity, how do we guarantee the correctness of counting, since in Mountain semantics it is the grounding of the denotation of plural nouns in the atomic denotations of singular nouns that gives plural nouns the correct counting structure? If we give up on atomicity, how can we guarantee the correct structure?

The answer is that in complete Boolean algebras it is not atomicity itself that guarantees correctness of counting, but a property that sets of atoms have, namely *disjointness*:

Correctness of counting:
If X is *disjoint* then *X has the structure of a complete atomic Boolean algebra with Z as its set of atoms.

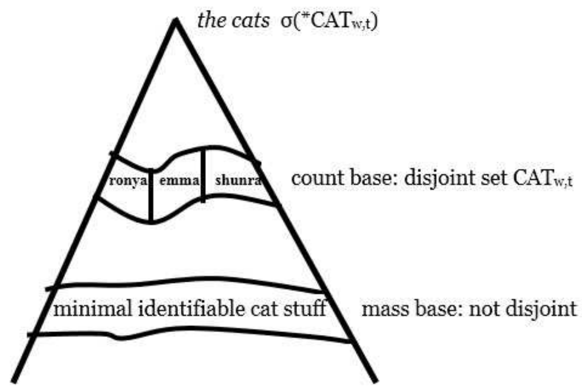
Iceberg semantics takes this as its lead: it lifts the denotation of *cat* and *cats* off the atomic bottom (in fact, it no longer requires there to be an atomic bottom at all), and assumes that their denotations are grounded in a *disjoint* base.

Formally, we assume that NPs are interpreted as *iceberg sets* [*i-sets*]:

i-sets: An i-set is a pair consisting of a body set and a base set, with the body generated by the base under $\sqcup$: X = < ***body****(X),* ***base****(X)* > *with* ***body****(X),* ***base****(X)* $\subseteq$ *B and* ***body****(X)* $\subseteq$ *****base****(X)*.

Iceberg semantics:
Singular noun *cat* and plural noun *cats* are counted in terms of the same disjoint base:
cat → < $CAT_{w,t}$, $CAT_{w,t}$>, with $CAT_{w,t}$ a disjoint set.
cats → <*$CAT_{w,t}$, $CAT_{w,t}$>

Landman (2016) extends iceberg semantics for NPs to DPs. The extension is based on the notion of i-object: a pair <**body, base**>, with the **body** ∈ B, **base** $\subseteq$ B and **body** = $\sqcup$**base**. i-objects are *count* if their base is disjoint, *singular* if their base is a singleton. Thus the sum of the cats will count as a count object relative to its count base $CAT_{w,t}$, but the same sum of cats will count as a mass object relative to, say, the set that contains the minimal identifiable cat-stuff:



1.4. The distinctions mass-count and neat-mess

The basic idea is the following. Let *X* be an i-set.

Mass -count i-sets: X is *count* iff **base**(*X*) is disjoint, otherwise *X* is *mass*.

Count nouns are interpreted as i-sets with a disjoint base, mass nouns as i-sets with an overlapping base.

This is the basic idea, but we need to refine the analysis in order to deal with borderline situations. For example, we want to allow mass nouns to denote, relative to certain indices, the empty i-set <Ø,Ø> (i.e. indices where the denotation of *mud* is empty). But technically, <Ø, Ø> is count, since technically the empty set is disjoint. If we require mass nouns to be interpreted at *every* index as a mass i-set, we don't allow empty interpretations. On the other hand, we don't want the interpretations of mass nouns to be completely unconstrained.

We will allow mass noun α to denote count i-sets in situation that are *borderline for* α. I don't have a theory of what counts as borderline situations for mass nouns, but they will include situations where the denotation of mass noun *gold* is the empty set or a singleton set. Allowing these denotations in should not challenge the status of *gold* as a mass noun, as long as they are marked as special cases.

Mass-count NPs: Let α be an NP and w,t an index.
w,t is α-*normal* if $[\![\alpha]\!]_{w,t}$ is not borderline for α.
α is *count* iff for every index w,t: $[\![\alpha]\!]_{w,t}$ is count.
α is *mass* iff for every α-*normal* index w,t: $[\![\alpha]\!]_{w}$ is mass.
Presupposition: ceteris paribus, contextually relevant indices are α-normal.

This means that in all contexts we interpret count nouns as count i-sets, and in normal contexts we interpret mass nouns as mass i-sets. And we presuppose that when we interpret mass noun α in context, we can assume that the relevant indices are normal.

Landman (2011) defines the notions of *neat* and *mess*, and proposes to use this distinction to characterize the difference between mass nouns like *kitchenware* (neat) and mass nouns like *mud* (mess). The notions below are changed a bit from Landman (2011):

Neat-mess i-sets:
X is *neat* iff **min**(**base**(X)) is disjoint and **min**(**base**(X)) generates **base**(X) under $\sqcup$, otherwise X is *mess*.

The intuition for neat mass nouns is that the distinction between singular and plural is not properly articulated in the base: **min(base)** $\subseteq$ **base** $\subseteq$ ***min(base)**.
Here too, the borderline case is the case where **min(base)** = base, which means that *count* should be *borderline neat*.

Neat-mess NPs: Let α be an NP and w,t an index.
α is *neat* iff for every index w,t: $[\![\alpha]\!]_{w,t}$ is neat and at every α-*normal* index: $[\![\alpha]\!]_{w,t}$ is neat mass.
α is *mess* iff for every α-*normal* index w,t: $[\![\alpha]\!]_{w}$ is mess mass.

This means then that neat mass nouns are neat in all contexts, and mass in normal contexts, and mess mass nouns are mess mass in all normal contexts.

As in Landman (2011), both distinctions *mass-count* and *neat-mess* are grounded in the notions of disjointness and overlap. The present theory differs from Landman (2011) mainly in doing more justice to the idea that there are different ways in which denotations can turn out to be mess mass. In particular, Landman (2011) defined i-sets to be mess mass if **min(base)** overlaps. My present view is that that was an unnecessary stipulation: on the present definition an i-set will also come out as mess mass, if, say, the base itself is atomless, hence has no minimal elements.

[My aim in Landman (2011) was to shift the focus of mass nouns away from looking vertically (atomic *versus* atomless) to horizontal (disjointness *versus* overlap). However, once this shift is established, and atoms are made irrelevant in the theory, there is actually no reason to exclude atomless bases, and in fact, there is reason to allow them. I discuss the case of *water* in Landman (2011), and suggest that *water* can be seen as a union of partitions of contextually minimal water parts, where a block of such a contextual partition may consist of one molecule of water and space around it, so the partition does not cut up water molecules, but it does cut up space. However, for a given contextual partition and a given block b, there are going to be alternative partitions where one of the blocks b' is the result of cutting off a bit of the space in b. Allowing both b and b' in the base brings us well on the way towards an atomless base.]

Iceberg semantics proposes to use bases for distinguishing count nouns (*disjoint base*) from mass nouns. As discussed here and in Landman (2016), for count nouns bases are used for counting, count-comparison, and distribution. I assume then that *disjoint base* is a grammatical property, a requirement on the semantics interpretation of count nouns. Except for the formulation in terms of bases, this is also what Rothstein (2011) proposes.

Rothstein moreover argues that it is important to interpret the grammatically relevant notion of disjointness as *contextual disjointness*. The denotations of nouns like *fence* and *body part* are not conceptually disjoint. But they are count nouns and that means that they are contextually coerced into disjointness by the *disjoint base* requirement on count nouns.

That disjointness *is* relevant for counting can be seen, for instance, by the bafflement of native speakers when you put a noun like *body part*, whose denotation is not conceptually disjoint, in a counting context that draws attention to the possibility of overlap:

(2) Fingers on the buzzers and answer directly when you ring the bell: How many body parts does a Hippopotamus have?

This means that Iceberg semantics for count nouns assumes that there are contextual strategies for eliminating overlap. The simplest is contextual restriction: make sure that you choose your fences disjoint in a counting context. This was suggested in Rothstein (2010). A more challenging operation, overlap elimination by doppelgänger, is discussed in Landman (2017).[This operation allows us to replace in a counting context, for the sake of interpretation, in overlapping objects, say, roads x and y, the overlap, $x \sqcap y$, by disjoint objects, $x_{x\sqcap y}$ and $y_{x\sqcap y}$, which are indistinguishable from $x \sqcap y$ and each other.]

For mass nouns, bases are used for distinguishing neat mass nouns from mess mass nouns. Here too, for neat mass nouns, bases are used for count-comparison and distribution. And here too, the neat-mess distinction can be argued to be a grammatical distinction based similarly on contextual disjointness. For more discussion, see Landman 2017ms, 2016.)

1.5. Iceberg semantics for numerical modifiers

Counting requires a disjoint base. We formalize that by introducing a presuppositional notion of cardinality in Iceberg semantics:

Presuppositional cardinality:

$$\mathbf{card} = \lambda Z \lambda x. \begin{cases} |(x] \cap Z| & \text{if Z is } \textit{disjoint} \\ \perp & \text{otherwise} \end{cases}$$

The cardinality of x relative to Z is the cardinality of the set of Z-parts of x, *presupposing* that Z is disjoint.

We can use this notion to clarify the connection between count nouns and counting.

Counting and mass: Let α be a mass noun, and β an NP-modifier.
If for all α-normal indices: $[\![\beta\alpha]\!]_{w,t} = \perp$, then $\beta\alpha$ is *infelicitous*.

Below we give a semantics for *at least three* α which involves the statement that $\mathbf{card}(\mathbf{base}(\alpha)) \geq 3$. This is only going to be defined at an index w,t if $\mathbf{base}(\alpha)$ is disjoint at w,t. For mass noun *mud*, such indices

are not *mud*-normal, hence we derive:

Fact: Numerical predicates cannot felicitously modify mass nouns:
at least three mud is infelicitous.

In this section, I discuss the semantics of numerical modifiers, mainly to set the stage for Part Two: the semantics of classifiers and measures. Landman (2016) contains discussion of other modifiers.

It is time to introduce the compositional mechanism of Iceberg semantics, and the central assumption (for English and Dutch) linking the syntax and semantics of complex NPs: the Head principle (for NPs):

Let H be an NP and C a complex NP with syntactic head H. So C = $[_{\text{NP}}\ \alpha\ \text{H}\ ]$ or C = $[_{\text{NP}}\ \text{H}\ \alpha]$.
H and C denote i-sets: $H = <\mathbf{body}(H), \mathbf{base}(H)>$ and $C = <\mathbf{body}(C), \mathbf{base}(C)>$.

Head principle for NPs:
$\mathbf{base}(C) = (\mathbf{body}(C)] \cap \mathbf{base}(H)$

The head principle says that the *base* of the interpretation of the complex C is the set of all Boolean parts of the *body* of the interpretation of C, *intersected* with the *base* of the interpretation of the syntactic head *H*.

The head principle is the assumption that in the interpretation of headed complex NPs, the semantics passes base-information up *from the head* H *to the complex* NP. As we will see, we make this assumption both for modifier structures (adjuncts) and for complement structures (classifiers).

We follow the semantics for numerical modifiers proposed in Landman 2004. This means that we assume a category of number relation expressions, like *at most*, *at least*, *exactly* and - (null), which are interpreted as number relations:

at least $\rightarrow \geq$ *at most* $\rightarrow \leq$ *exactly* $\rightarrow =$ **-** $\rightarrow =$ number relations.
These expressions combine through application with number expression *three* - which denotes the number 3 **-** to form *number predicates*, denoting sets of numbers:

at least three → λn.n ≤ 3 *at most three* → λn.n ≤ 3 **-** *three* → λn.n=3

We derive ***numerical*** *relations* from number predicates by compositing the number predicate with **card**:

Numerical predicates: at least three → $\lambda n.n \geq 3 \circ \mathbf{card}$
$= \lambda Z \lambda x.\ \mathbf{card}[x,Z] \geq 3$

Hence, composition derives as the interpretation of *at least three*, the relation that holds between x and base set Z if the cardinality of x relative to Z is at least three.

This is the analysis of Landman (2004). We now need to cast this in the Iceberg semantics framework. We assume that numerical modifier phrases like *at least three* denote functions from i-sets to i-sets. This means that we need to turn the numerical relation into a function from i-sets to i-sets. We do that by the following schema:

Shift numerical relations to functions from i-sets to i-sets:
α a variable over numerical relations, P over i-sets

$$\lambda\alpha\lambda P.\begin{cases} <\mathbf{body}_{P,\alpha}, \mathbf{base}_{P,\alpha}> & \text{if } \mathbf{pres}_{P,\alpha} \\ \perp & \text{otherwise} \end{cases}$$

$\mathbf{body}_{P,\alpha} = \mathbf{body}(P) \cap \alpha(\mathbf{base}(P))$
$\mathbf{base}_{P,\alpha} = (\mathbf{body}_{P,\alpha}] \cap \mathbf{base}(P)$
$\mathbf{pres}_{P,\alpha} = \mathbf{base}(P)$ is disjoint

-α here is a numerical relation like $\lambda X \lambda x.\ \mathbf{card}[x,X] \geq 3$. This relation inherits its presupposionality from **card**. This brings in the presupposition $\mathbf{pres}_{P,\alpha}$ on the interpretation of the numerical modifier, that the base of the interpretation of the head it modifies must be disjoint (so the head noun must be a count noun).
- $\mathbf{base}_{P,\alpha}$ is the base of the interpretation of the complex. This is determined by the Head principle.
- $\mathbf{body}_{P,\alpha} = \mathbf{body}(P) \cap \alpha(\mathbf{base}(P)$
Look at what this means for the interpretation of *at least three*, i.e. numerical relation $\lambda Z \lambda x.\ \mathbf{card}[x,Z] \geq 3$:

$\mathbf{body}_{P,\lambda Z\lambda x.\,\mathbf{card}[x,Z]\geq 3} = \mathbf{body}(P) \cap \lambda x.\ \mathbf{card}[x, \mathbf{base}(P)] \geq 3.$
$= \lambda x.\ \mathbf{body}(P)(x) \wedge \mathbf{card}[x, \mathbf{base}(P)] \geq 3$

This is just the interpretation that you would get in Mountain semantics, except, of course, that cardinality is not defined in terms of atoms, but in terms of the disjoint base of the interpretation of the head.

Let us apply the interpretation for *at least three* to the interpretation of *cats*, $<{}^*CAT_{w,t}, CAT_{w,t}>$, and to avoid issues of triviality, let us assume that $CAT_{w,t}$ is a disjoint set of at least three cats. Filling in all the details, we derive as the interpretation of *at least three cats*:

at least three cats → < **body, base** >
body = $\lambda x.{}^*CAT_{w,t}(x) \wedge \mathbf{card}[x, CAT_{w,t}] \geq 3$
base = $(\mathbf{body}] \cap CAT_{w,t}$

Given that the numerical modifier is purely quantitative (and our non-triviality assumption)
$(\mathbf{body}] = {}^*CAT_{w,t}$, hence: $\mathbf{base} = CAT_{w,t}$.

So if $CAT_{w,t}$ = { r(onya), e(mma), s(hunra), t(ijger) }, we derive for *at least three cats*:
body = { r⊔e⊔s, r⊔e⊔t, r⊔s⊔t, e⊔s⊔t, r⊔e⊔s⊔t } a set of strict pluralities
base = { r, e, s, t }

Note that the base is not a subset of the body (but, of course, the body is generated by the base).

The analysis shows that we have achieved what we set out to achieve: we have given an Iceberg semantic analysis of numerical modifiers which counts sums in the body of the interpretation of *cats* in terms of the elements in the base of the interpretation of *cats*.

The base is also used for the other hallmark of the count domain: *distribution*, for example with count distributor *each*. In (3), a sum of cats in the denotation of *three pet cats* counts as a sum of *three* in relation to the base of the interpretation of the subject *three pet cats*, which is $PET_{w,t} \cap CAT_{w,t}$ (see Landman 2016 for Iceberg semantics for such modifiers).

(3) *Three pet cats* should *each* have their own basket.

Each in the VP distributes the VP property to the elements of this set: (3) expresses that if in your house there is a sum x of three pet cats, the parts of x that are in $\mathrm{PET}_{w,t} \cap \mathrm{CAT}_{w,t}$ should have their own basket.

2. CLASSIFIERS, MEASURES AND PORTIONS

Head principle for NPs:
base(C) = **(body**(C)**]** ∩ **base**(H)
The base of C is the part set of the body of C intersected with the base of H.

In the previous section we illustrated the head principle in the case of numerical modifiers. We are now concerned with the following consequence of the principle:

Fact: If **base**(H) is disjoint, then **base**(C) is disjoint.

This means that we should find the following mass-count properties for complex nouns:

Corollary: Mass-count
The mass-count characteristics of the head inherit up to the complex:
Complex noun phrases are count if the head is count.
Complex noun phrases are mass if the head is mass.

We explore this in the context of classifier and measure phrases.

2.1. *Classifiers and measures in English and Dutch*

Classifiers and measures are pseudo-partitives in English, they take element *of*, which is neither a preposition, nor a partitive marker, and in fact, a similar marker is absent in Dutch (as shown in (4a)); they take mass or plural NPs as complements, but not singular NPs (as shown in (4b)); classifiers and measures agree in number with numerical modifiers in English, and so do classifiers in Dutch (as shown in (4c)):

(4) a. One pack *of* rice One kilo *of* ball bearin**gs**
Eén pak rijst Eén kilo kogellager**s**

b. One pack of *rice* One kilo of *ball bearing**s***
Eén pak *rijst* Eén kilo *kogellager**s***
#One kilo of *ball bearing*
#Eén kilo *kogellager*
c. ***Two** pack**s*** of rice ***Two** kilo**s*** of rice ***Twee** pakk**en*** rijst

As Doetjes (1997) points out, measures in Dutch are in general not specified for number: specifying plurality on the measure generally triggers a classifier interpretation for the measure (cf. Doetjes 1997; Rothstein 2011, and caveats in Landman 2017.):

(5) a. Ik heb twee kilo rijst gekookt *measure*
I have two kilo[-] rice cooked
b. Ik heb twee liters melk gehaald *classifier*
I have two liters milk fetched

Furthermore, in Dutch, classifiers and measures agree in gender with determiners (thanks to Hanna de Vries for bringing this up): in (6), the neuter demonstrative *dat* agrees with the neuter measure *pond* and not with the masculine noun *suiker*:

(6) Je hebt één pond suiker nodig. ***Dat*** *ene* **pond** *suiker* gaan helemaal op.
You need one pound of sugar. That one pound of sugar will be used up completely.

Most remarkable from a semantic point of view is the cheerful shifting between measure and classifier interpretations (as in (7) and (8)):

(7) Joha's mother said to him: "Go and buy me *two liters of milk*." So Joha went to buy her *two liters of milk*. He arrived home and knocked on the door with *one liter of milk*. His mother said to him: "I asked you for two liters. Where is the second one?" Her son said to her: "It broke, mother." [γ] *measure → classifier*

(8) a. There was also the historic moment when I accidentally flushed a *bottle of lotion* down the toilet. That one took a plumber a few hours of manhandling every pipe in the house to fix. [γ] *classifier*

b. This is one of the few drain cleaners that says it's safe for toilet use, so I flushed a *bottle of it* down the toilet and waited overnight. [γ] *measure*

[I thank Larry Horn for introducing me to the use of [γ] to indicate 'googled' examples.]

Rothstein (2011) proposes (following, among others, Landman (2004)) semantic interpretations for classifier phrases and measure phrases along the following lines:

Classifier interpretation: *three glasses of wine* → ***three*** ∩ (***glass***(***wine***))
glass applies to ***wine***; ***three*** intersects with the result.

On the classifier interpretation, the *semantic head* is the classifier ***glass***. This will derive classifier interpretations like the following:

three *glasses* of wine = three *glasses* filled with wine

These interpretations are *container classifier* interpretations. We will discuss other classifier interpretations below, but they will follow the same semantic composition.

Measure interpretation: *three liters of wine* → (***three*** ∘ ***liter***) ∩ ***wine***
three composes with ***liter***; the result intersects with ***wine***.

On the measure interpretation, the *semantic head* is the non-measure ***wine***. This will derive measure interpretations like the following:

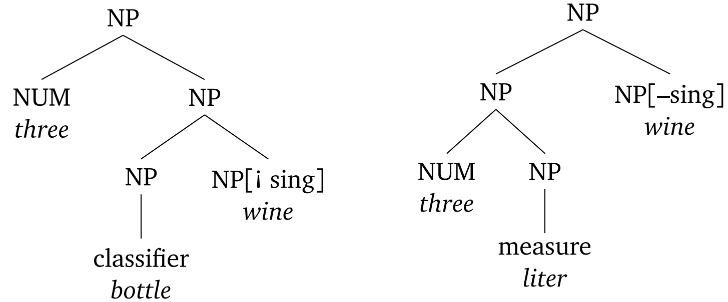
three *liters* of wine = *wine* to the amount of three liters
three *boxes* of books = *books* to the amount of three boxfuls

The Iceberg semantics for classifiers and measures that I will develop here will follow these semantic derivations.

Rothstein (2011, in press) goes one step further, and argues, with evidence from Mandarin Chinese, Modern Hebrew, Hungarian, Dutch

and English, that the semantic difference between measure phrases and classifier phrases corresponds to a difference in syntactic structure:

Classifier structure: *Measure structure:*



Syntactic head: classifier *Syntactic head:* NP[–sing]

Rothstein's proposal for measure phrases:

1. Measure phrases have measure structure and measure interpretation. So syntax and semantics are matched.
2. The syntactic head of the measure phrase is the non-singular noun phrase, NP[–sing].
3. Semantically, NP[–sing] is reinterpreted as a mass noun.

Rothstein (2011) argues that measure phrases pattern with mass nouns (we discuss this in section 2.4.2). This is what motivates the third assumption: on Rothstein's analysis NP[–sing] is both the syntactic and the semantic head of the measure construction. If it is semantically reinterpreted as a mass noun, we expect the measure phrases to pattern with mass nouns.

While I find the arguments in Rothstein (2011) and Rothstein (in press) that Mandarin and Hebrew measure phrases have this measure structure compelling, I do not accept her arguments for Dutch and English.

Rothstein's strongest argument for this assumption in Dutch and English concerns the contrast in (9), in a context where the price of the cups itself is irrelevant:

(9) a. ✓twee *dure* bekers ijs
✓Two *expensive* cups of icecream

b. #Twee *dure* liter ijs
#Two *expensive* liters of icecream

Rothstein argues as follows:
-(9a) allows in principle two syntactic structures, based on the classifier structure: [two [[***expensive cups***] (of) *icecream*]] and [two [*expensive* [***cups*** (*of*) ***icecream***]]].
The first structure is, by assumption, irrelevant; the second forms the basis for the felicitous natural interpretation.
-(9b) allows only the measure structure: [[two ***expensive*** *liters*]] (of) *icecream*]].
But *expensive* cannot modify measure *liters*, so (9b) is infelicitous.

I want to place the data in (9) in a wider context. Look at classifier example (9c), again in a natural situation where it is not the cup that is melted:

(9) c. #Twee *gesmolten* bekers ijs.
#Two *melted* cups of icecream.

The observation is that (9c) also seems infelicitous if it is only the icecream that is melted. If so, the semantics apparently cannot derive ***melted***(***cups***(***icecream***)) with interpretation: ***cups***(***melted***(***icecream***)), i.e. skipping over, so to say, the cups. (The difference with (9a) is that in (9a) the natural interpretation does not skip over the cups: it is the "cup *cum* icecream experience" that you pay for in a certain kind of restaurant.)

But this is directly relevant for the example (9b): if we cannot get the skip-over interpretation in classifier derivations, we surely would not expect to be able to get a hop-skip-jump interpretation (***two*** ∘ ***liter***) ∩ (***expensive***(***icecream***)) of the measure derivation (***two*** ∘ ***expensive***(***liter***)) ∩ ***icecream*** in (9b).

The conclusion is that the measure semantics that is shared between Rothstein and me all by itself accounts for the differences observed in (9), without making any assumptions about the syntax.

But there is another point to be made. While [γ]-searching for variants of the expression (9b) and (9c) does not yield a rich crop, such examples *do* occur (thanks to Richard Larson for stressing this point):

(10) a. To add jungle vines to your plantation, select *one* ***mixed*** *pound of seedy grapes*, red, blue and green. Eat them tenderly so as not to bruise the seeds. [γ]

b. Patty uses five pounds of the clay to make a vase; she gives this vase to Kevin. She also gives *the five* ***remaining*** *pounds of clay* to Kevin (perhaps with a note about the pleasures of the potter's wheel). [γ]

c. *20,000* ***shredded*** *pounds of ice* make a pretty awesome sledding hill. [γ]

Since the examples in (10) involve measures, and (10b,c) clearly measure interpretations, these examples should be *ungrammatical* on Rothstein's analysis, which seems rather harsh.

On my analysis, such examples are not ungrammatical, and the examples in (10) can be accommodated as follows. Classifiers, measures, and adjectival modifiers all have interpretations (basically) as functions from i-sets to i-sets. This means, technically, that there could be *another* derivation possibility: compose the classifier/measure with the adjective, and then follow the derivation as usual. And this, when worked out properly, generates exactly the skip-over reading:

$$(\boldsymbol{cups} \circ \boldsymbol{melted})\ (\boldsymbol{icecream})) = \qquad (\boldsymbol{cups}(\boldsymbol{melted}(\boldsymbol{icecream}))$$
$$(\boldsymbol{two} \circ (\boldsymbol{liter} \circ \boldsymbol{expensive})) \cap \boldsymbol{icecream} = (\boldsymbol{two} \circ \boldsymbol{liter}) \cap (\boldsymbol{expensive}(\boldsymbol{icecream}))$$

My suggestion is that interpreting the adjective via composition with the classifier/measure is not an operation that is readily available, and it may be indeed strictly unavailable for speakers who don't accept cases like (10) at all (like Susan Rothstein). But, the suggestion is that, for others, applying this composition is an option that is in some contexts available, and it makes skip-over interpretations possible.

So the evidence from adjectives does not point at the *need* to assume the measure syntax, and in fact the measure syntax may be a bother more than a boon, which means that *ceteris paribus*, I'd rather not assume that structure.

Now, we have already seen above in (6) that gender agreement in Dutch is always with the classifier or the measure, never with NP[–plur]. I do not have the space to discuss the complexities of number-agreement here, but I argue in Landman (2017) that the situation is in essence similar: the facts do not justify the assumption that in phrases with a measure interpretation NP[–plur] is the syntactic head. Rothstein's measure structure gives NPs with a measure phrase, like *at least three liters of wine*, the same structure as NPs with numerical modifiers, like *at least three boys*, that is, a modifier structure. Given the syntactic differences observed, this requires a syntactic theory in which the *same* modification geometry is input to two very different agreement mechanisms. To me this seems once again more a bother than a boon, and *ceteris paribus*, I'd rather not assume that structure.

My attitude towards Rothstein's third assumption, the systematic reinterpretation of plural NP[–sing] as a mass noun, is similar, though for different reasons. Note first that the reinterpretation involves a shift from the plural noun to a *neat* mass noun, which is, in Rothstein's theory, a very minimal shift from a count set of object-context pairs to the corresponding set of objects, which is *neat* mass. So the shift is not grinding, which is shifting to a *mess* mass interpretation. This is important, since there is no evidence for obligatory reinterpretation of plural count nouns as mess mass nouns in this context. Look at example (11):

(11) The truck toppled over and five hundred *boxes of ball bearings were* rolling over the highway, causing a major traffic jam.

This example is nicely ambiguous between a classifier interpretation, where it is five hundred boxes that rolled over the highway, and a measure interpretation, where it is ball bearings to the amount of 500 boxfuls that rolled over the highway. But it is precisely on the measure interpretation that it is ball bearings rolling over the highway. There is no natural sense in which that interpretation involves *by necessity* a reinterpretation of *ball bearings* as a *mess* mass noun, *ball bearing mess*.

But the assumption that the reinterpretation involved is the minimal type readjustment of the plural count noun to a neat mass noun brings in a puzzle. As is well-known, the italicized context in (12) is a context where, in English, bare singular count nouns cannot naturally occur:

(12) The Thai restaurant was advertised as the award winning restaurant from two consecutive years, so we decided to try Thai food for the first time in our lives…and there was *cockroach in the soup*!!! [γ]

Rothstein (2011) accounts for the differences observed by Cheng et al. (2008) between cases like (12) in English and corresponding examples in Mandarin, by assuming that in Mandarin the bare noun corresponding to *cockroach* is *neat* mass, and, because of that, you get a count interpretation (cockroaches swimming in the soup), while in English in (12), the bare noun shifts to a *mess* mass noun by *grinding*.

But now we have a puzzle in English: the minimal shift from the count noun to the neat mass noun that Rothstein postulates in measure phrases would resolve the grammatical mismatch in (12) much more efficiently than grinding, and it would get the same interpretation for (12) as in Mandarin, an interpretation that is not available in English.

Clearly, then, shifting from count noun interpretations to neat noun interpretations is available in English only under very restricted circumstances that do not include cases like (12). Now, I can come up with a story myself for why this would be so (say, based on competition), but *I* have the option here to choose the simpler solution: the shift to neat mass noun interpretations doesn't happen, because it doesn't exist.

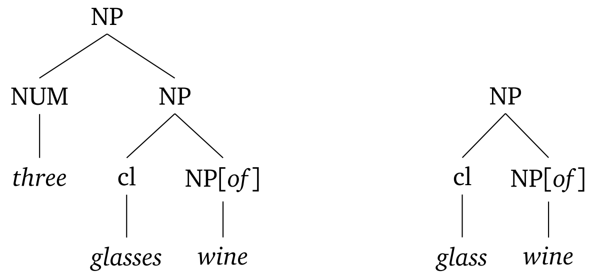
In this paper, then, I will make the following alternative assumptions:

1. Measure phrases have the classifier structure and a measure interpretation. So there is a *mismatch* between syntax and semantics.
2. The syntactic head of the measure phrase is the measure.
3. Semantically, the measure itself is *mass*.

If the measure is *mass* and the measure is the head of the measure construction, then, by the Head principle, the measure phrase itself comes out as mass. This means that we will be able to derive, with a standard syntax, the result about measure phrases that Rothstein's reinterpretation stipulation was concerned with.

2.2. *Semantics of classifiers*

Classifier structure: three glasses of wine



We will focus on deriving the semantics of classifier phrase *glass of wine*, and assume that semantic pluralization and modification with *three* takes place on the classifier interpretation derived.

We start out with mass noun *wine* and count noun *glass*, with interpretations:

noun: *wine* $\rightarrow$ $WINE_{w,t}$ = <$\text{WINE}_{w,t}$, **base**($\text{WINE}_{w,t}$)>
noun: *glass* $\rightarrow$ $GLASS_{w,t}$ = <$\text{GLASS}_{w,t}$, $\text{GLASS}_{w,t}$>, with $\text{GLASS}_{w,t}$ disjoint.

We assume that the noun *glass* becomes a classifier *glass*, and this involves shifting its interpretation from an i-set to a function from i-sets to i-sets:

Classifier: glass $\rightarrow$ **classifier**[$GLASS_{w,t}$] a function from i-sets to i-sets

It will be useful here to specify a general schema for the interpretation of classifiers, so that below, when we are concerned with different classifier interpretations, we only need to specify the variable parameters for the different interpretations.

General classifier interpretation schema: [Let P be a variable over i-sets, α a count i-set]

$$\textbf{classifier}[\alpha] = \lambda P.\begin{cases} <\textbf{body}_P, \textbf{base}_P> & \text{if } P \text{ is mass or plural (and } \textbf{pres}_P) \\ \perp & \text{otherwise} \end{cases}$$

body$_P$ = **...**
base$_P$ = **(** **body**$_P$**]** $\cap$ **base**(α) Head principle
pres$_P$ = **...**

pres$_P$ specifies potential further presuppositions (we see this below in the discussion of contents classifiers). Apart from that, the schema tells us that, if the base of the noun that the classifier is based on is given, we only need to specify **body**$_P$.

Given all this, we will give a semantics for container classifiers and various types of portion classifiers, in particular, shape classifiers and contents classifiers.

2.3. *Semantics of container classifiers*

The first classifier interpretation we are concerned with is the container interpretation:

three *glasses* of wine = three *glasses* filled with wine

In the classifier interpretation schema α = <$\text{GLASS}_{w,t}$, $\text{GLASS}_{w,t}$>. We specify **body**$_P$:

Container interpretation:
body$_P$ = λx.$\text{GLASS}_{w,t}$(x) $\wedge$ **body**(P)(**contents**$_{\textbf{[GLASS, P,c]},w,t}$(x))
The set of glasses containing **body**(P)

The basis of the container interpretation is the function **contents**.

$\text{contents}_{\textbf{[GLASS, WINE,c]},w,t}$: B $\rightarrow$ B $\cup$ $\perp$

The contents function specifies for a container at an index its relevant contents: the relevant stuff that is in the container. The function is constrained by a further parameter sequence:
[container property **GLASS**, contents property **WINE**, context **C**].

This parameter sequence is used to impose constraints on contents. For instance, an obvious constraint is:

Containers and contents:
$\mathbf{contents}_{[\mathbf{GLASS},\ \mathbf{WINE},\mathbf{c}],w,t}(x) = y$ presupposes that x is a glass and requires that y is wine.

There are all sorts of other constraints on relevant contexts:

- For glasses and wine, **contents** concerns *liquid contents* and not the *gaseous contents*, i.e. we ignore the air hovering above the wine inside the glass.
- **contents** requires the amount of wine in the glass to be within a certain range.

Look at (13):

(13) [*Next to Susan is a wineglass with less than a centimeter wine left in it. Susan to Fred:*]

a. You see that *wineglass*? Can you fill it up please?
b. #You see that *glass of wine*? Can you fill it up please?

(13a) is felicitous (in fact, frequent), (13b) is infelicitous: what counts as *a glass of wine* is relative to what is standard for **GLASS** and **WINE** and the context **C**, and this means that a glass with an amount of wine in it below the standard doesn't count as a glass of wine.

What counts changes when we vary the parameters: the *same* amount of *single malt* as in (13) in a *scotch glass* may well count as a *glass of Lagavulin*. The *same* amount of wine as in (13) in the *same* wine glass *would* have counted as a *glass of wine* when Susan was pregnant.

-The wine may be mixed with non-wine but only to a certain extent. In classical Greece wine was always drunk mixed with water, some drinks naturally allow water, some an olive, a piece of lemon, a grape pit,... without affecting the contents. Thus, it is still *a glass of mescal*, even if it has a worm in it. But not every additive can be ignored: if you pour diesel oil in my glass of *Chassagne Montrachet*, it is no longer *a glass of wine* (and also the end of a beautiful friendship).

We continue with the semantic derivation. [For readability I will suppress the parameter index **[GLASS, WINE,C]** on **contents**, and use extensional property variables, instead of the proper intensional ones, see Landman 2017ms for discussion.]

$\mathbf{body}_P = \lambda x.\text{GLASS}_{w,t}(x) \wedge \mathbf{body}(P)(\mathbf{contents}_{w,t}(x))$
$\mathbf{base}_P = (\!\!(\ \mathbf{body}_P\ ]\!\!] \cap \text{GLASS}_{w,t} = \mathbf{body}_P$

We apply to the i-set interpretation of *wine* and get:

[NP *glass of wine*] → <**base, base**>
$\mathbf{base} = \lambda x.\text{GLASS}_{w,t}(x) \wedge \text{WINE}_{w,t}(\mathbf{contents}_{w,t}(x))$
The set of glasses that contain wine.

Now we observe: *glass* is a count noun, hence $\text{GLASS}_{w,t}$ is disjoint. That means that the base of the container interpretation of *glass of wine* is disjoint, and we have derived:

Fact: glass of wine, with *glass* a container classifier, is a *singular count* NP.

2.4. Portion and measures interpretations

Before we analyze portion readings and measure readings, we establish the basic distinction that the semantics will have to support. We just derived that container classifier readings are count readings. We will see that portion classifier readings, even though they may well concern mass stuff, pattern with count nouns, so portion readings also ought to come out as count. We show, following Rothstein (2011), that measure readings pattern with mass nouns.

2.4.1. Portion classifiers interpretations are count

So far we have followed Rothstein (2011) and distinguished container classifier readings from measure readings. We add to that now portion readings:

Three glasses of wine:
container reading three *glasses* containing wine
measure reading *wine* to the amount of *three glassfuls*

portion reading three *wine portions* each of which is the contents of a *glass* of wine

We find the portion reading for *sixteen glasses of wine* in (13):

(14) I have put sixteen glasses of wine ready in a row, of different sizes, as you can see. We are going to put all of it into the brew in the course of two hours. As you will see, ***most** of the sixteen glasses of wine* are put into the soup during the first half an hour of brewing.

First note that the container reading is not relevant: we are not going to put the glasses in the brew. Note secondly that the measure reading is not relevant either: the glasses are specified as being of different sizes. The essence of the measure reading is that *glass* as a measure is interpreted as *glassful*, an amount that may be contextually given, but is fixed. This is irrelevant in (14), because what we pour in at different times is indeed wine, but not glassfuls of wine, not every time the same fixed amount. Thus we have a true portion reading in (14): we pour into the brew *wine in portions of different size*.

Now look at the interpretation of *most* in (14). *Most* in (14) involves a comparison in terms of the *number of portions of wine*, not in terms of the amount of wine (i.e. if during the first half an hour we pour into the brew the contents of 12 scotch glasses, and during the remainder one and a half hour the contents of 4 half-liter beer glasses, (14) is true). This means that the portion reading is a count reading.

So indeed, portion readings are readings that denote stuff, like mass nouns, but are count. Other portion classifiers are *shape classifiers* like *hunk, slice, stack* (of hay), *strand* (of hair):

A *hunk* of meat = meat in the shape of a *hunk*
A *slice* of meat = meat in the shape of a *slice*

Shape classifiers are portion classifiers, like measures they denote stuff if NP[–plur] denotes stuff:

A *hunk* of meat is *meat*.
A *kilo* of meat is *meat*.

But shape classifiers are count:

(15) a. I don't eat ✓*much* /#*many meat* sliced nowadays. *mass*
b. I don't eat #*much* /✓*many slices of meat* nowadays *count*
c. *Most* of the slices of meat are pork *count comparison*

As in (14), *most* in (15c) makes a comparison in terms of the *number of slices* of meat, not in terms of the weight or volume of the meat.

Partee & Borschev (2012) discuss portion readings (tentatively) as a subcase of measure readings. Schvarcz (2014) argues with Hungarian data that portion readings are count. Khrizman et al. (2015) argue that portion readings differ systematically from measure readings, and they offer cross-linguistic evidence to this effect. I present some of the cases discussed in Khrizman et al. (2015) in section 2.7.

2.4.2. Measure interpretations are mass

I start with a preamble about partitives. Partitives with singular count DPs like *of the cat* pattern with partitives with mass DPs like *of the wine* (they are called *entity* partitives by Helen (1997)):

(16) a. ✓*much* of the wine/ #*each* of the wine
b. ✓*much* of the cat / #*one* of the cat

Landman (2017) argues that if we assume that the semantics of the partitive disallows singular i-objects as the partitive complement, then partitives with singular count DPs can only be felicitous by shifting the singular count object (e.g. <ronya,ronya>) to a mass object (e.g. <ronya,**mass-base**>). On the analysis given in Landman (2017), this makes the partitive NP *of the cat* indeed a mass NP. This analysis involves what has been called *grinding*, but is better called *opening up*, since the shift opens up internal structure for measurement. Thus, (17) is treated as a case of *opening up*:

(17) After the kindergarten party, *much of my daughter* was covered with paint.

With the *opening up* shift, the *mass*-semantics of *much* in terms of, say, area-measure becomes available, and with an appropriate contextual restriction, (17) *means that much of the surface area of my daughter* was covered with paint.

On the suggested analysis, *opening up* is *always* involved in partitives with singular count DPs. Examples which involve *opening up* in partitives with *plural* DPs can also be found, (18) is a [γ]- example:

(18) While our current sensibilities are accustomed to the tans, taupes, grays and browns, in their time *much of the rooms* as well as the cathedral proper would have been beautifully painted. [γ]

But such cases are actually rare, hard to find, and even so, not everybody is happy with them (Susan Rothstein, for instance, doesn't much like (18)). The analysis of partitives sketched here plays actually no further role in the present paper. The marginality of cases like (18) does. Rothstein's argument that measure phrases pattern with mass nouns concerns mass effects in partitives with plural measure DPs. But, in contrast with cases like (18), the measure cases below are *normal* examples, generally accepted as perfectly felicitous, and not rare either. [Well, to my surprise I got nothing when I [γ]-ed with *kilos*, but when I had the luminous idea to replace *kilos* by *kg*. the examples streamed in.] This means that Rothstein's examples cannot be explained away as instances of *opening up* along the lines of (18): they tell us something important about measure phrases.

With this in mind, we come to the examples. We look at *much* in English and *het meeste-most* in Dutch and the contrasts in (19) and (20):

(19) a. #*Much* ball bearings was sold this month.
b.#?*Much* of the ball bearings was sold this month.
c. ✓*Much* of the ten *kilos* of ball bearings was sold this month

(20) a. #*Het meeste* kogellagers is deze maand verkocht.
(✓*De meeste* kogellagers zijn deze maand verkocht.)
b.#?*Het meeste* van de kogellagers is deze maand verkocht.
c. ✓*Het meeste* van de tien *kilo* kogellagers is deze maand verkocht.

-(19a) and (20a) are completely out, because *much* and *het meeste* select for mass nouns.
-(19b) and (20b) are not much better (no [γ]-hits). If felicitous, they

are understood via *opening up*, that is, (20b) suggests a peculiar mass reading.
-But (19c) and (20c) are perfectly fine, and express a comparison of the total body of ball bearings relating to the measure *kilo*.

We see the same contrast in (21) (based on examples from Rothstein 2011):

(21) a. ***Many*** *of the twenty kilos of potatoes* that we sampled at the food show were prepared in special ways.
b. ***Much*** *of the three kilos of potatoes* that I ate had a pleasant taste.

-(21a) has a portion interpretation. We went with a group to the food show, and in each booth they served us a kilo-size portion of potatoes. In quite a number of these booths they had made an effort to prepare the potatoes in a special way.
-(21b) has a measure interpretation. I ate a three kilo-size portion of potatoes: it consisted of four very big potatoes, and 10 tiny blue-green ones. The latter tasted, well, peculiar.

Actually, note that (21b) can be used to express that *individual potatoes* had a pleasant taste: it is not *required* that *potatoes* itself shifts to mass.

Rothstein's example (22) is also instructive:

(22) a. #***Each*** of the *six boxes of books* that I read had more than 300 pages.
b. ✓***Much*** of the *six boxes of books* that I brought could have stayed at home.

The VP in (22) forces reference to *books* rather than *boxes*, since boxes don't have pages. Only a measure interpretation accesses books, since portions of books don't have pages either. *Each* is incompatible with the measure reading, so (22a) is infelicitous. But (22b) is perfectly fine, and has a measure interpretation whereby the totality books is compared in terms of the measure *boxful*.

What this means is that 'the very same thing' may count as *much of the six boxes of ball bearings*, which is mass, and as *many of the ball bearings*, which is count. In Iceberg semantics, the difference is located in the base: the base of the first, but not that of the second involves the measure *boxful* in its derivation.

2.5. Semantics of portion classifiers

2.5.1. Shape classifiers

The Iceberg semantics of shape classifiers like *hunk, slice, heap, strand,*... is straightforward. Shape classifiers are portion classifiers based on count nouns. As functions from i-sets to i-sets the semantics expressed by their body is just intersection:

count noun: hunk $\rightarrow$ $<\text{HUNK}_{w,t}, \text{HUNK}_{w,t}>$, with $\text{HUNK}_{w,t}$ disjoint.

Shape classifier interpretation:
$\mathbf{body}_P = \lambda x.\ \mathbf{body}(P)(x) \wedge \text{HUNK}_{w,t}(x)$
The stuff that is **body**(*P*) and hunk.

We feed the portion interpretation for *hunk* into the classifier interpretation schema of section 2.2, apply to the interpretation of *meat*, and derive (after simplification):

hunk of meat $\rightarrow$ $<\mathbf{base}, \mathbf{base}>$
$\mathbf{base} = \lambda x.\text{MEAT}_{w,t}(x) \wedge \text{HUNK}_{w,t}(x)$
The stuff that is meat and hunk.

Since shape classifiers are based on count nouns, the base derived for *hunk of meat* is disjoint, so we derive for shape classifiers the same fact as for container classifiers:

fact: hunk of meat with *hunk* a shape portion classifier is a *singular count* NP.

Actually, shape classifiers satisfy a stronger property:

Contextual separateness:
If $\text{HUNK}_{w,t}(x)$ and $\text{HUNK}_{w,t}(y)$ and $x \neq y$, then x and y are *contextually separated:*
They behave in the context as separate single bodies under environmental transformations.

What I mean by this is that two disjoint parts of one hunk of meat only become themselves hunks when they are cut and we can pick them up separately. Similarly, two disjoint parts of the soup become portions of soup when we put them in separate bowls. And two segments of one hair are not two strands of hair, strands of hair are hairs, complete objects. Defining the notion of *contextual separation* goes beyond the scope of this paper. It relates to the topological considerations in the semantics of mass and count nouns in Grimm (2012) (though separatedness is more than topological apartness: two slices of meat lying op top of each other are separate slices, but not topologically apart).

2.5.2. Contents classifiers

Above, we analyzed the container reading of *three glasses of wine*: three glasses *containing* wine. In this section we are concerned with the contents reading: wine *contained* in three glasses. This reading is a portion reading, which, as is clear from this informal description, involves the *converse* of the containment relation (to be defined with the **contents** function). Central in the analysis of contents readings is a presupposition that the function **contents** is *normal on* relevant indices w,t, in the following sense:

Normality of contents:
$\text{content}_{\mathbf{[GLASS,WINE,c]}}$ is *normal on* w,t iff if $\text{GLASS}_{w,t}(x)$ and $\text{GLASS}_{w,t}(y)$ and $x \neq y$
then $\mathbf{content}_{\mathbf{[GLASS,WINE,c]w,t}}(x)$ and $\mathbf{content}_{\mathbf{[GLASS,WINE,c]w,t}}(y)$ are disjoint.

A consequence of normality is that in normal contexts the function $\mathbf{contents}_{w,t}$ is one-one, and hence the inverse function $\mathbf{contents}_{w,t}^{-1}$ is defined.

In section 2.3 the container classifier interpretation of *glass* was derived directly from the interpretation of the noun *glass*. For the contents interpretation, we *shift* the interpretation of the noun *glass* from a set of containers to the set of portions that are the contents of those containers:

Contents interpretation of NP *glass:*
$[_{NP}\ glass\ ] \rightarrow <\mathbf{base}, \mathbf{base}>$
$\mathbf{base} = \lambda x.\text{GLASS}_{w,t}(\mathbf{contents}_{w,t}{}^{-1}(x))$
The set of portions that are contents in w,t of glasses.

It is this NP-interpretation of *glass* that enters into the classifier interpretation schema. As promised above, for contents classifiers we specify an additional presupposition on the classifier interpretation schema:

$\mathbf{pres}_P = \mathbf{contents}$ is normal on the context.

Under this presupposition, the schema derives the following body:

Contents classifier interpretation:
$\mathbf{body}_P = \lambda x.\ \mathbf{body}(P)(x) \wedge \text{GLASS}_{w,t}(\mathbf{contents}_{w,t}{}^{-1}(x))$
The set of **body**(*P*) portions that are contents in w,t of glasses.

We apply to the interpretation of *wine* and derive:

glass of wine $\rightarrow <\mathbf{base}, \mathbf{base}>$
$\mathbf{base} = \lambda x.\text{WINE}_{w,t}(x) \wedge \text{GLASS}_{w,t}(\mathbf{contents}_{w,t}{}^{-1}(x))$
The set of wine portions that are glass-contents in w,t.

Now we argue as follows.
Let $x, y \in \mathbf{base}$ and let $x \neq y$.
Then $\mathbf{contents}_{w,t}{}^{-1}(x) \neq \mathbf{contents}_{w,t}{}^{-1}(y)$, simply because $\mathbf{contents}_{w,t}$ is a function.
So x and y are the contents in w,t of *different glasses*. It follows now from the normality presupposition that portions of wine x and y are disjoint. Hence we have derived, also for contents portion classifiers:
Fact: glass of wine, with *glass* a contents portion classifier is a *singular count* NP.

2.6. *Semantics for measures*

2.6.1. Measure functions

Measure functions are functions from B into the set of non-negative real numbers ($\mathbf{R}^+$), where the null-object in B is mapped onto 0. In general:

Measure functions:
$\mu_{w,t}: B \rightarrow \mathbf{R}^+ \cup \{\perp\}$ where $\mu_{w,t}(0) = 0$

Definedness:
$\mathbf{def}(\mu_{w,t}(x))$ iff $\mu_{w,t}(x) \neq \perp$

In the context of natural language measures we cannot ignore the possibility that objects with defined measure values have parts whose measure value is not defined. For instance, the measure *broadloom meter* measures the length of carpet with a standard width of 3.66 meter. A role of carpet has a defined *broadloom meter* value, but this value is measured along one side of the roll, hence, only parts that go from that side across the roll have themselves a defined *broadloom meter* values.

I will be concerned here with *additive continuous* measure functions, like the measure functions for volume and weight. Additivity is the following principles:

Additivity:
If X is a countable disjoint subset of B and for every $x \in X$:
$\mathbf{def}(\boldsymbol{\mu}_{\mathbf{w,t}}(x))$,
then $\mu_{w,t}(\sqcup X) = \Sigma(\mu_{w,t}(x)\colon x \in X\}$

This entails, for x and y such that $\mathbf{def}(\boldsymbol{\mu}_{\mathbf{w,t}}(x - y))$, $\mathbf{def}(\boldsymbol{\mu}_{\mathbf{w,t}}(y - x))$ and $\mathbf{def}(\boldsymbol{\mu}_{\mathbf{w,t}}(x \sqcap y))$:

$$\mu_{w,t}(x \sqcup y) = \mu_{w,t}(x - y) + \mu_{w,t}(y - x) + \mu_{w,t}(x \sqcap y)$$

I will presuppose a standard definition of continuity for measure functions, which entails the Intermediate Value Theorem:

Intermediate Value Theorem:
If $x \sqsubseteq y$ and $\mu_{w,t}(x) < \mu_{w,t}(y)$ then for every $r \in \mathbf{R}^+$:
if $\mu_{w,t}(x) < r < \mu_{w,t}(y)$ then $\exists z \in B\colon x \sqsubseteq z \sqsubseteq y$ and $\mu_{w,t}(z) = r$

Take volume as an example: continuity entails that when a body grows from x with defined volume $\mu_{w,t}(x)$ to y with defined volume $\mu_{w,t}(y)$, its volume passes through *all* intermediate values. The intermediate value theorem tells us that we do not let undefinedness interfere with continuity. Take once again the measure *broadloom meter*: when we measure the carpet roll along the defined dimension, the measure values increase through *all* real numbers from 0 to the broadloom value of the carpet roll: we do not go through undefined values when we measure parts of the roll along *this* dimension.

2.6.2. Measure i-sets: additive continuous measures are mass

A measure function $\mu_{w,t}$ is, of course, a set of pairs of objects in B and values in $B^+ \cup \{\bot\}$:

$$\mu_{w,t} = \{<b, \mu_{w,t}(b)>: b \in B\} \subseteq B \times (\mathbf{R}^+ \cup \{\bot\})$$

I propose to use this view of the measure function as a set of pairs to extend Iceberg semantics to measures: we generalize the notion i-set to measure i-set:

measure i-sets: Given measure function μ_{wt}.
A (μ_{wt}) measure *i-set* is a pair <**body, base**>, where **body** and **base** are sets of object-$\mu_{w,t}$ value pairs, and the **base** generates the **body** under sum.

The notion *generated under sum* means that we need to impose a Boolean structure onto the set of pairs of object-measure values. Since every object in B has a value under $\mu_{w,t}$ in $R^+ \cup \{\bot\}$, lifting the Boolean structure from B to $\mu_{w,t}$ is lifting the structure in a trivial way to $D \times (R^+ \cup \{\bot\})$:

$$B_{\mu,w,t} = \{<b, \mu_{w,t}(b)>: b \in B\}$$
$$<x,\mu_{w,t}(x)> \sqsubseteq_{B\mu_{w,t}} <y,\mu_{w,t}(y)> \text{ iff } x \sqsubseteq_B y$$
$$<x, \mu_{w,t}(x)> \sqcup_{B\mu_{w,t}} <y, \mu_{w,t}(y)> = <x \sqcup_B y, \mu_{w,t}(x \sqcup y)>$$

The Boolean algebra $\mathbf{B}_{\mu,w,t}$ is clearly isomorphic to **B** (since the measure part plays no role in the definitions).

We now interpret measure *liter* as a measure i-set, with body the additive continuous volume measure function $\mathbf{liter}_{w,t}$:

$[_{\text{measure}}$ *liter* $] \rightarrow LITER_{w,t} = <\mathbf{body}(LITER_{w,t}), \mathbf{base}(LITER_{w,t})>$ with:
1.$\mathbf{body}(LITER_{w,t}) = \mathbf{liter}_{w,t}$
2. $\mathbf{base}(\mathbf{liter}_{w,t}) \subseteq \mathbf{liter}_{w,t}$ and $\mathbf{base}(\mathbf{liter}_{w,t})$ generates $\mathbf{liter}_{w,t}$ under $\sqcup_{B\mu,w,t}$

We now argue:

Fact: If $\mu_{w,t}$ is an additive continuous measure function, $< \mu_{w,t}$, **base**> is a measure i-set, and the base is *disjoint*, then the base can only contain pairs of the form <x,0> or <x,⊥>

Proof: Let $\mu_{w,t}$ be an additive continuous measure function, $< \mu_{w,t}$, **base**> a measure i-set,
base *disjoint* and $\mu_{w,t}(x) > 0$ and $<x,\mu_{w,t}(x)> \in$ **base**.
Then $0 \sqsubseteq x$ and $\mu_{w,t}(0) < \mu_{w,t}(x)$. Let $0 < r < \mu_{w,t}(x)$. By the Intermediate Value Theorem, there is a y such that $0 \sqsubseteq y \sqsubseteq x$ and $\mu_{w,t}(y) = r$.
Then $<y, \mu_{w,t}(y)>$ is generated by **base**, i.e. $\mu_{w,t}(y) \in$ ***base**.
But obviously, since y is a proper part of x, $<y, \mu_{w,t}(y)>$ can only be generated from pairs $<z, \mu_{w,t}(z)> \in$ **base**, with z a proper part of x. This means that **base** is *not disjoint*.
Hence, if **base** cannot it cannot contain pairs of the form <x,r>, with r >0.

Does this show that the base of additive continuous measures cannot be disjoint? Not quite by itself, because the theory does not disallow *infinitesimal point objects*.

Think of models for space and time. As is well know, we can represent real time intervals and real space solids as infinite sets of point, regular open sets of *points*. If we include the points in our model they are disjoint, and in defining measure functions for space and time we set the measure values of the points to 0 (or ⊥). Regular open sets of points get positive real measure values. If we generalize this picture from space to matter, and allow infinitesimal disjoint *matter* points, we could let the bases consist of matter points and generate all measure values from a disjoint base of points.

But note, these would not be points of time, space or space-time, but *points of matter*, which can be seen as an extreme version of Demokritos' theory of atoms. Such points of matter have, of course, no physical reality: while *space* may be made up of *space points*, I will not accept that similarly *wine* is made up of *wine points*. This really is an extension of the arguments in Landman (2011) against 'homeopathic semantics': *salt worth one salt molecule* is *mass* noun phrase. Iceberg semantics does not accept that, because of the mass nature of the noun phrase, the objects in its denotation must split into proper parts that are themselves in the denotation of *salt* (i.e. that it is *salt* all the way down). Similarly, Iceberg semantics does not accept that *salt* is built from *salt-points*:

> *Iceberg semantics:*
> Try to develop the semantics of mass nouns and count nouns in naturalistic structures. Try not to *disregard* natural parts and structure. Try not to *include* non-natural. structure.

[Note: This semantic naturalism does not, in my view, extend to fundamental ontological notions of when an object counts as 'one', where an object begins and ends, etc. I argued already in Landman (1992) for events that, as far as *grammar* is concerned, the latter notions are contextual and pragmatically manipulated, so naturalistic parsimony is not necessarily appropriate there. I will discuss these matters in the context of the semantics of mass and count nouns in Landman (2017), projected.]

So I add to the technical theory an Icebergian axiom of faith:

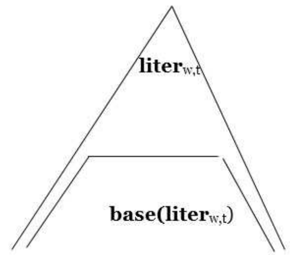
> *Iceberg Dogma:* Iceberg semantics *rejects* points of matter.

With this we conclude:

> *Corollary:* Continuous additive measures are interpreted as *mess mass* measure i-sets: measure i-sets with an *overlapping* base. In other words: measures are mass.

So what *is* **base**($LITER_{w,t}$)?

Intuitively, in Iceberg semantics the *base* contains the 'contextually minimal' stuff that the *body* is made of. The above discussion suggests that for measure functions, the generating base must be a set that is closed under parts. Since measures are extensional, it is natural to think of the base as the set of *all* part-measure value pairs whose measure value is smaller than a certain value.



Let $\mathbf{m}_{\mathbf{liter},w,t}$ (m for short) be a **contextually** given measure value. For concreteness think of **m** as the lowest volume that our experimental precision weighing scales can measure directly (rather than extrapolate).

$\text{liter}_{w,t}{}^{\leq \mathbf{m}} = \{<x, \mathbf{liter}_{w,t}(x)>: \mathbf{liter}_{w,t}(x) \leq \mathbf{m}\ \}$
The set of object-liter value pairs where the liter value is less than or equal to **m**.

We set:

$[_{measure}\ \textit{liter}\ ] \rightarrow <\mathbf{liter}_{w,t}, \mathbf{liter}_{w,t}{}^{\leq \mathbf{m}}>$

$\mathbf{liter}_{w,t}{}^{\leq \mathbf{m}}$ is closed downward and hence a heavily overlapping base. Since ***all*** pairs $<d, \mathbf{liter}_{w,t}>$ with $\mathbf{liter}_{w,t}(d) \leq \mathbf{m}$ are in $\mathbf{liter}_{w,t}{}^{\leq \mathbf{m}}$, $\mathbf{liter}_{w,t}{}^{\leq \mathbf{m}}$ has no problem generating all elements with higher volume value as sums of base elements with $\sqcup_{B,\mathbf{liter}w,t}$: $\mathbf{liter}_{w,t} \subseteq {}^*\mathbf{liter}_{w,t}{}^{\leq \mathbf{m}}$.

I summarize where we are. I made the standard assumption that measure *liter* denotes an additive continuous measure function. I have implemented this in *the most literal way* in Iceberg semantics: measure *liter* denotes a measure i-set: it satisfies *the same requirement* of the body being generated under sum from the base as all other nominal expressions. I derived from that and from general concerns about additive measure functions that measures are mass.

2.6.3. The general measure interpretation schema

We add operations $^{\uparrow}$ and $^{\downarrow}$ that shift between sets of objects and sets of object-measure value pairs in the obvious way:

For $X \subseteq B$: $^{\uparrow}X = \{<x, \mathbf{liter}_{w,t}(x)>: x \in X\}$
For $Z \subseteq B_{\mathbf{liter}.^{w,t}}$: $^{\downarrow}Z = \{x \in B: <x, \mathbf{liter}_{w,t}(x)> \in Z\}$

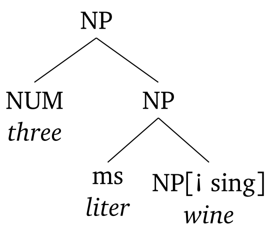
Further, as a last step on the way to the general measure interpretation schema, it will be useful to introduce a *mixed* type of i-set, with the body a set of objects, and the base a set of object-$\boldsymbol{\mu}_{wt}$ value pairs: *measure* $i^{\downarrow}$*-sets*:

Given measure function $\boldsymbol{\mu}_{w.t}$.
A ($\boldsymbol{\mu}_{w.t}$) *measure* $i^{\downarrow}$*-set* is a pair <**body, base**>, where the **body** is a set of objects and the **base** is a set of object-$\boldsymbol{\mu}_{wt}$ value pairs and $^{\downarrow}$**base** generates the **body** under $\sqcup$.

What will happen is the following. The measure *liter* denotes a measure i-set, body and base are pairs of objects-$\mathbf{liter}_{w,t}$ values. The measure phrase *three liters of wine* will denote a *measure* $i^{\downarrow}$*-set*: the body denotes a set of objects, but the base still denotes a set of object-$\mathbf{liter}_{w,t}$ values. This assumption allows us to keep track of the relevant part of the measure function in the derivation, up to the level where, say, in the partitive measure phrases of section 2.4.2 like *much of the twenty kilos of potatoes*, we want *much* to access the measure function.

I assume a syntax and semantics for measure phrases along the following lines:

Classifier structure:



Measure interpretation:
(***three*** $\circ$ ***liter***) $\cap$ ***wine***

Syntax and semantics are mismatched: ***three liter*** is a semantic unit, but not a syntactic constituent. Measure *liter* is the head of the

measure phrase.

We have so far interpreted measure *liter* as $LITER_{w,t}$, a measure i-set. But this measure i-set needs to shift to a function, **measure**($LITER_{w,t}$), which can fulfil the grammatical functions: it should compose with the interpretation of number predicate *three*, and intersect the result with the interpretation of *wine*.

Given what was said above, we assume: **measure**(α) shifts measure i-set α to a function from number sets and measure i-sets to measure $i^{\downarrow}$-sets.

General measure interpretation schema:
[Let *P* be a variable over i-sets *N* over sets of numbers,
α a measure i-set.]

$$\mathbf{measure}[\alpha] = \lambda N \lambda P. \begin{cases} <\mathbf{body}_{P,N}, \mathbf{base}_{P,N}> & \text{if P is mass or plural} \\ \perp & \text{otherwise} \end{cases}$$

$\mathbf{body}_{P,N}$ = ($\mathbf{body}(\alpha) \circ N) \cap \mathbf{body}(P)$ Function composition set of objects
$\mathbf{base}_{P,N}$ = $^{\uparrow}$($\mathbf{body}_P$] $\cap$ $\mathbf{base}(\alpha)$ Head principle set of object-α_{wt} value pairs

[I have left potential further presuppositions out of the schema for simplicity.]

We apply the general measure schema to measure *liter*, number predicate *three*, and NP[–plur] *wine*, and we derive:

three liters of wine → <**body, base**>
body = $\lambda x.\mathbf{liter}_{w,t}(x){=}3 \wedge WINE_{w,t}(x)$
The wine that has volume three liters.
base = $\{<y, \mathbf{liter}_{w,t}(y)>: \mathbf{liter}_{w,t}(y) \leq \mathbf{m} \wedge \exists x[WINE_{w,t}(x) \wedge y \sqsubseteq x]\}$

$^{\downarrow}$**base** = $^{\downarrow}\mathbf{m}_{\mathbf{liter},w,t}{}^{\leq} \cap \lambda y.\exists x[WINE_{w,t}(x) \wedge y \sqsubseteq x]$
The stuff that is part of the wine and has volume at most **m**.

We derive the following fact:

Fact: Measure phrase *three liters of wine* is a *mass* NP.

Since $\mathbf{m}_{\mathbf{liter},w,t}{}^{\leq}$ is not disjoint, neither is ${}^{\downarrow}\mathbf{m}_{\mathbf{liter},w,t}{}^{\leq}$ (which is $\lambda y.\ \mathbf{liter}_{w,t}(y) \leq \mathbf{m}$).
Obviously, then, (in the normal case) the intersection is not going to be disjoint either.

We derive a similar semantics for *three kilos of potatoes* with standard additive weight function $\mathbf{kilo}_{w,t}$, and *three boxes of books* with non-standard measure function $\mathbf{box}_{w,t}$:

three kilos of potatoes: $\lambda x.\mathbf{kilo}_{w,t}(x)=3 \wedge {}^{*}\text{POTATO}_{w,t}(x)$
three boxes of books: $\lambda x.\mathbf{box}_{w,t}(x)=3 \wedge {}^{*}\text{BOOK}_{w,t}(x)$

Three kilos of potatoes is mass, because the base that we derive (given a similar choice of base for the measure as for *liter*) is the set of *potato-**parts*** that measure up to value $\mathbf{m}_{\mathbf{kilo}}$, and this set is not disjoint.

It is important to note that the elements of ${}^{\downarrow}\mathbf{base}$ for *three kilos of potatoes* are *Boolean* parts of the sum of potatoes involved: they are not themselves required to be potatoes or sums of potatoes (in the denotation $^{*}\text{POTATO}_{w,t}$ of plural noun *potatoes*). At the same time, on a non-shifted interpretation, the elements of the **body** *are* in *POTATO, i.e. without shifting they are sums of potatoes, not just potato mass. A nice example showing this effect concerns the Dutch count noun *bonbon* in (23):

(23) *[at Neuhaus in the Galerie de la Reine in Brussels]*
Customer: Ik wou graag 500 gram bonbons.
I would like 500 grams of pralines.
Shop assistant: Eén meer or één minder?
One more or one less?

The shift *Ah, just squeeze enough into the box so that it weighs exactly 500 grams* would be a *faux pas* at this particular location.

2.7. Shifting measures to classifiers

Khrizman et al. (2015), in their discussion of the count nature of portion interpretation, discuss various operations that shift measures to portion classifiers, and argue that the interpretations derived are count. I will briefly sketch these shifts here.

In all the following cases we derive $\lambda P.\langle \mathbf{base}_P, \mathbf{base}_P \rangle$, with $\mathbf{base}_P$ disjoint.

Case 1: Shift the measure to a container interpretation.

This is what we saw in example (7) and what we see in example (24):

(24) I broke a liter of milk

We assume property $\text{CONTAINER}_{\mathbf{c}}$ that maps index w,t onto disjoint set $\text{CONTAINER}_{\mathbf{c},w,t}$, a set of containers at w,t whose nature is determined by context $\mathbf{c}$.

We shift measure $LITER_{w,t}$ to singular count i-set ***one liter container*** which feeds into the classifier interpretation schema. The compositional details are given in Khrizman et al. (2015). We derive the following base:

$\mathbf{base}_P = \lambda x.\text{CONTAINER}_{\mathbf{c},w,t}(x) \wedge \mathbf{body}(P)(\mathbf{contents}_{w,t}(x)) \wedge$
$\mathbf{liter}_{w,t}(\mathbf{contents}_{w,t}(x))=1$
The set of containers containing one liter of body(P).

This is, of course a disjoint set (because $\text{CONTAINER}_{\mathbf{c},w,t}$ is disjoint).

liter of milk $\rightarrow \langle \mathbf{base}, \mathbf{base} \rangle$
$\mathbf{base} = \lambda x.\text{CONTAINER}_{\mathbf{c},w,t}(x) \wedge \text{MILK}_{w,t}(\mathbf{contents}_{w,t}(x)) \wedge$
$\mathbf{liter}_{w,t}(\mathbf{contents}_{w,t}(x))=1$

With this, (24) expresses that I broke a one liter container of milk.

Case 2. Shift the measure to a portion interpretation: free portion interpretations.

This is what we find in (25):

(25) He drank three liters of Soda pop, one in the morning, one in the afternoon, one in the evening.

Here the protagonist drank three portions of Soda pop, of one liter each. In analogy to the previous case, we assume a property $\text{PORTION}_{\mathbf{c}}$ that maps index w,t onto disjoint set $\text{PORTION}_{\mathbf{c},w,t}$, a set of portions at w,t whose nature is determined by context $\mathbf{c}$.

We shift measure $\mathit{LITER}_{w,t}$ to singular count i-set ***one liter portion***, which feeds into the classifier interpretation schema. The compositional details are the same as for container shift. We derive the following base:

$\mathbf{base}_P = \lambda x.\ \text{PORTION}_{\mathbf{c},w,t}(x) \wedge \mathbf{body}(P)(x) \wedge \mathbf{liter}_{w,t}(x)=1$
The set of one liter portions of body(P).

Again this is disjoint set (because $\text{PORTION}_{\mathbf{c},w,t}$ is disjoint).

liter of Soda pop → <**base**, **base**>
$\mathbf{base} = \lambda x.\ \text{PORTION}_{\mathbf{c},w,t}(x) \wedge \text{SODA POP}_{w,t}(x) \wedge \mathbf{liter}_{w,t}(x)=1$

With this, (25) expresses that he drank three disjoint one liter portions of soda pop.

Case 3: Free portions interpretations for container classifiers

We have seen above that container classifiers like *bottle, glass, cup, box* can have measure interpretations. We assume that these interpretations involve non-standard measure functions: $\mathbf{bottle}_{w,t}$, $\mathbf{glass}_{w,t}$, $\mathbf{cup}_{w,t}$, $\mathbf{box}_{w,t}$. The measure function cupw,t fixes a volume that count as the contents of 'one cup' (US: 1 cup = 0.236588 liters [γ]).

Now, under case 2 we shifted standard measure *liter* to a portion classifier. With that we may well expect that we can, with the same operation, shift the non-standard *measure* interpretation of container classifiers to portion classifiers as well: Thus as a measure, *cup* is interpreted as a measure i-set based on measure function $\mathbf{cup}_{w,t}$. With the portion shift operation of case 2, we shift this to portion classifier ***one cup portion***. We derive the following base:

$\mathbf{base}_P = \lambda x.\ \text{PORTION}_{\mathbf{c},w,t}(x) \wedge \mathbf{body}(P)(x) \wedge \mathbf{cup}_{w,t}(x)=1$
The set of one-cup size portions of body(P)

cup of Soy sauce → <**base**, **base**>

$\mathbf{base} = \lambda x.\ \text{PORTION}_{\mathbf{c},w,t}(x) \wedge \text{SOY SAUCE}_{w,t}(x) \wedge \mathbf{cup}_{w,t}(x)=1$

Look at (26):

(26) Pour *three cups of soy sauce* in the brew, the *first* after 5 minutes, the *second* after 10 minutes, the *third* after 15 minutes. I have a good eye and a very steady hand, so I pour ***them*** straight from the bottle.

As usual, the relevant reading of *three cups of soy sauce* in (26) is not a container classifier reading: I don't add the cups to the brew. The relevant reading is not a contents classifier reading either: the soy sauce is never in a cup when I pour, the portions of soy sauce in question are not the contents of any container in $\text{CUP}_{w,t}$. The reading is not a measure reading either, because I *count* what I pour in: *one cup-size portions*. This is the free portions interpretation: portions that are tied to the measure function $\mathbf{cup}_{w,t}$, not to cups.

2.8. In sum

We have derived the following readings for classifiers and measures:
three glasses of wine:

container:	three glasses filled with wine	*count*
contents:	three portions of wine, each the contents of a glass	*count*
measure:	wine to the amount of three glassfuls	*mass*
portion:	three one glassful size portions of wine	*count*

three liters of wine:

measure:	wine to the amount of three liters	*mass*
portion:	three one liter size portions of wine	*count*
container:	three one liter containers filled with wine	*count*
contents:	three portions of wine, each the contents of a one liter container	*count*

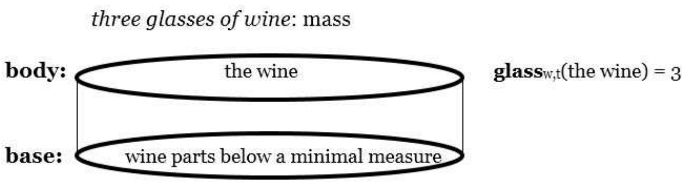
Compositionality.
The above is a systematic account of the different interpretations of classifier and measure phrases and their mass-count characteristics. This becomes possible in Iceberg semantics, because the mass-count distinction does not just apply to lexical nouns, but to noun phrases in general, and because of the Head principle, which gives a compositional defini-

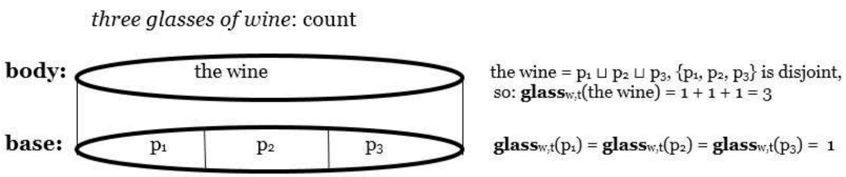
tion of bases for complex noun phrases.

Of course, anybody can postulate an uninterpreted feature system for mass-count, and extend it to complex noun phrases. But, when it comes to portion readings and Rothstein's observation about the mass nature of measure phrases, an uninterpreted feature system will be stipulative and uninsightful. As we have seen, I think Rothstein's *own* stipulation that derives the mass nature of measure phrases is problematic as well.

The present paper derives the mass nature of measure phrases from general principles of Iceberg semantics (bases generate bodies under sum) and from a detailed analysis of the nature of bases for measures. This account is not only non-trivial, but the argumentation involved has, I think, enormous potential for the semantics analysis of prototypical mess mass nouns as well.

The Problem of Portions.
Mountain semantics suffered from the Problem of Portions. Iceberg semantics replaces atomicity by disjointness. Removing atoms, and characterizing mass-count in terms of bases, means that *the same wine* can count *simultaneously* as mass and as count, solving the Problem of Portions:





ACKNOWLEDGEMENTS

The basic format of Iceberg semantics was presented, in the context of the semantics of mass nouns, in Landman (2011). The compositional theory was presented at the Workshop on Countability at the Heinrich Heine University in Düsseldorf in 2013 (see also Landman 2016). However, the basic idea of Icebergs was planted in my head long before that by Barbara Partee, who at many times expressed to me that in her opinion, atomicity is peripheral to Link's theory, the core being plural denotations being understood as grounded in singular ones. I am very grateful to Barbara for continuing to insist on this: in the end, working on mass nouns convinced me that the idea was right, though I continue to hold that atomicity is the core of Link's theory, and though working out Barbara's intuition turned out to be harder than either of us might have expected.

The Düsseldorf Workshop really worked as a catalyst for me, and I thank the organizers, Hana Filip and Christian Horn, and the participants, especially Scott Grimm and Manfred Krifka, for their stimulating presence and discussion.

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