Making space for measures*

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1. Introduction: prepositional measure phrases

The primary goal of this paper is to offer a starting point for a discussion of the syntax and compositional semantics of examples like (1), which have not been, to the best of our knowledge, ever studied before despite the fact that they provide a number of important insights on the syntax and semantics of measure praises and pseudo-partitives:

(1) a. Don't touch the steering wheel if you have drunk **over five glasses of wine**.
b. I ate **around a pound of jam**.
c. The mass of the meteorite was estimated at **under 66 tons**.
d. I was swimming **between a kilometer and a mile** four days a week.

Several issues arise in relation to prepositional measure phrases. In regard to their internal composition, it is not usually assumed that measure phrases, especially if they do not combine with a substance NP (1c,d), denote entities, whereas the normal semantics of spatial prepositions requires an entity-denoting complement. Secondly, the interplay of their external syntax and semantics raises questions exactly mirroring those concerning their internal structure: spatial PPs are generally not taken to denote entities, which means that a PP is generally not a good substitute for an argument NP, yet prepositional measure phrases have the same distribution as measure phrases without the preposition.

To resolve these issues we propose that measure nouns denote **abstract containers** located in a vertically oriented half-open **one-dimensional space**. This proposal and its formalization allows us to account for their behavior along the following lines:

- **measure phrases are entities** and can therefore combine with prepositions
- their **vertical orientation** follows from the container concept
- and thus some of the constraints on **the choice of prepositions** are explained
- while their **interpretation** is **unchanged**
- the **algebra of scalar addition and multiplication**, i.e., the scalar structure of measures, follows from the properties of one-dimensional space
- the lack of other dimensions makes it possible to account for the **container-content ambiguity** noted for pseudo-partitives (Selkirk 1977, Landman 2004, Grimshaw 2007, Rothstein 2009a, Partee and Borschev 2012, Duek and Brasoveanu 2015, etc.)

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The most important contribution of our proposal we see, however, in reconstructing degrees as entities in concrete 1D space. If our approach is on the right track, it eliminates altogether the need to postulate a special semantic type or sort for degrees, leading to an ontological simplification and accounting naturally for the nominal syntax of measure nouns, which do not differ from other nouns in their ability to combine with determiners, numerals and modifiers.

2. Syntactic preliminaries

Whereas many different approaches to the semantics of spatial prepositions (Wunderlich 1991, Zwarts and Winter 2000, Kracht 2002, Bateman, Hois, Ross and Tenbrink 2010, etc.) have been proposed, very little attempt has been made to extend this work to PP measures. Before this can be done, however, it is necessary to determine the constituency of PP measures, both concerning the combination of the preposition with the measure phrase and the internal constituency of the pseudo-partitive.

2.1 The syntax of the preposition

To the best of our knowledge, almost no prior work was done on measure uses of spatial prepositions. The one exception is the so-called prepositional numerals, exemplified in (2), which gave rise to two competing syntactic analyses: while Plank 2004 proposes that the preposition combines with the NP as a whole, Corver and Zwarts 2006 argue for a structural ambiguity approach (3):[1]

(2) Ik reken op [rond de twintig kinderen]. — Dutch
I count on round the twenty children
I count on approximately twenty children.

(3) a. There is [[around ten] cot deaths] per year in Finland. — measure
b. Draw a circle [around [ten dots]]. — spatial

Two sets of problems arise for the structural ambiguity approach: on the one hand, as noted by Plank 2004, the preposition may assign case to the noun as well as the cardinal (4), and on the other hand, the existence of PP measures without a cardinal (5) leaves no place for structural ambiguity: it seems extremely unlikely that the indefinite article can be analyzed as the sole complement of the preposition:

(4) My žili tam s dva goda/ okolo dvux let. — Russian, Plank 2004
we lived there from [two years]$_{ACC}$/ about [two years]$_{GEN}$
We lived there for about two years.

(5) a. around a pound
b. between a kilometer and a mile

Examples like (5) clearly show that spatial prepositions may combine with measure NPs without giving rise to a locative interpretation, which means that in measure PPs involving cardinals the constituency is most likely to be the same, with the cardinal and the measure noun forming a constituent before combining with the preposition. If the

[1] On the semantic side, some research has been done on the semantics and pragmatics of the non-local *up to* (Nouwen 2008, 2010, Schwarz, Buccola and Hamilton 2012, Blok 2013, 2016, [to appear]), where the connection to the directional preposition was noted and exploited to support the proposed analysis, but no formal link was established.

constituency in (3a) is still assumed for prepositional numerals like (2), then examples like (5) are predicted to be potentially structurally ambiguous, with no empirical evidence for this conclusion for the two structures in (6) and the additional problem of providing the semantics for the combination of a locative preposition with a cardinal, as well as for its combination with a measure NP:

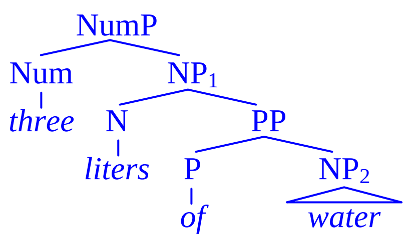
(6) a. [about two] years
b. about [two years]

It seems reasonable therefore to postulate only the structure in (6b) for prepositional measures (5) and prepositional cardinals (3) both. Two questions then arise: how to account for the measure interpretation of some combinations of locative prepositions with NPs and what structure to assume for PP measure pseudo-partitives.

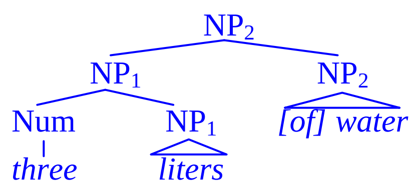
2.2 The syntax of pseudo-partitives

Both syntactic and semantic literature on pseudo-partitives is divided as to their internal structure, with two diametrically opposing views gaining the utmost prominence: while one (see Klooster 1972, Selkirk 1977, Lehrer 1986, Vos 1999, Grimshaw 2007, Landman 2015, Ruys 2017, among others) proposes that the pseudo-partitive is headed by the measure noun with the substance NP merged as its complement (7a), the other (Gawron 2002, Rothstein 2009a, b, 2011a, b, etc.) suggests that it is the substance noun that is the head of the pseudo-partitive and that the measure phrase is merged as its specifier (7b):[2]

(7) a. measure head, cascade

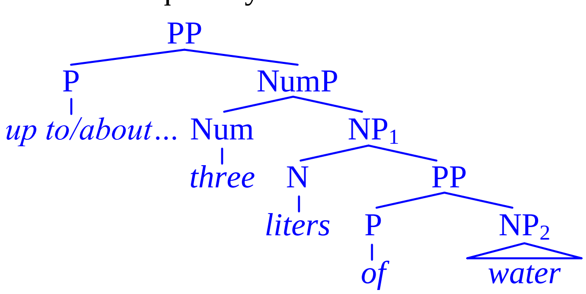


b. substance head, specification



Clearly, the preposition of measure PPs should combine with NP_1 in both structures. For the constituency in (7b) this implies straightforward extension from PP measures to pseudo-partitives, while for the constituency in (7a) some clarification is needed. Indeed, the structure in (8) is problematic: on the one hand, it would seem to be categorially a PP yet has the distribution of a noun phrase and on the other hand, the preposition would arguably combine with something that denotes a substance (water, in (8)) rather than what denotes a quantity.

(8)



[2] The label Num is used in (7) for expository purposes only with no positive commitment to the mode of combining a cardinal with its sister implied. While we will assume the cascade structure and semantics of Ionin and Matushansky 2006, nothing in particular hinges on this decision here.

Nonetheless, a number of syntactic reasons can be provided for adopting the cascade structure in (8) despite the issues that it gives rise to (and which will be addressed in section 3.3). First of all, NP-internal agreement (concord) clearly demonstrates that it is the measure noun that is the head of the pseudo-partitive (Ruys 2017, cf. van Gestel 1986):

(9) a. die éne liter water — Dutch, Ruys 2017
that.C one liter.C water.N
that one liter of water

b. het onsje cocaïne
the.N metric.ounce.DIM.N cocaine.C
the ounce of cocaine

Secondly, evidence that at least in one language the head-complement relation obtains between N_1 and the substance NP comes from the visible construct state morphology for container nouns in Hebrew, as shown in (10).[3] Since the Semitic construct state is unquestionably analyzed as a reflection of the head-complement relation (Ritter 1987, 1988, Borer 1999, 2005, etc.), the structure in (7b) would seem to be ruled out for at least one language:

(10) šloša bakbukey yayin — Hebrew, Rothstein 2011a
three bottles.CS wine
three bottles of wine

To avoid the unmotivated proliferation of different syntactic/semantic realizations for what is arguably the same phenomenon (pseudo-partitives), it would seem reasonable to adopt one and the same treatment for all languages in the absence of clear evidence to the contrary. However, further evidence for the same cascade structure can be provided from a number of different languages on the basis of case-assignment to and inside the pseudo-partitive, c-selection and word order (see Ruys 2017 and Matushansky, Ruys and Zwarts 2017 for further details; some novel evidence from Basque (Matushansky et al. 2017) is presented in fn. 8 below).

3. Measure nouns as abstract containers

Prepositional measure phrases present a problem for semantics that is independent of constituency and labeling and also independent of the presence of substance nouns or numerals: how can *spatial* prepositions like *below* and *over* combine with measure NPs

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[3] It could be objected that measure nouns do not show construct-state morphology in pseudo-partitives:

(i) šaloš/šloša kilogram-im/*kilogram-ey/kilo agvaniyot
three.F/M kilogram$_{M}$-PL/kilogram$_{M}$-PL$_{CS}$/kilo$_{M}$ tomatoes
three kilograms of tomatoes

The contrast between measure nouns and container nouns would have to be explained in any theory, so the hypothesis that measure nouns in Modern Hebrew do not have a dedicated construct-state form does not add to the complexity of the proposal. Furthermore, construct-state morphology was clearly visible in measure pseudo-partitives in Biblical Hebrew:

(ii) ‘ăśereṯ ṣimd-êy ḵerem
ten $_{CS}$ acre-PL$_{CS}$ vineyard
ten acres of vineyard (Isaiah 5:10)

like *20°F* or *a liter (of vodka)* to yield a *non-spatial* (measure) reading for the resulting combination?

(11) a. The temperature is below 20°F.
b. We drank over a liter of vodka.

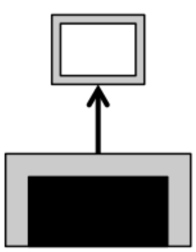
If we assume that measure phrases denote in a separate ontological domain of *degrees* (see Seuren 1973, Cresswell 1976, Heim 1985, Kennedy 1999, etc.), then the relevant prepositions must have an additional, but closely related meaning that operates on degrees. Alternatively, we could assume a general metaphorical connection between space and degrees (Lakoff and Johnson 1980, Lakoff and Núñez 2000) on the basis of which degrees of a measure scale can always be metaphorically described as positions on the vertical axis (see Plank 2004, Nouwen 2016 for numerals). While allowing spatial prepositions to work with measures, as if they had a vertical position, this would still require a metaphorical mapping from the normal measure denotation of measure phrases to an additional spatial denotation. Our proposal is that such a mapping is not necessary, because measure phrases already denote in the same domain as other phrases that can combine with prepositions. Just like material objects (like trees and tables), measures 'live' in space, but what makes them different is that they are one-dimensional. More specifically, measures are a special sort of abstract containers in 1D space.

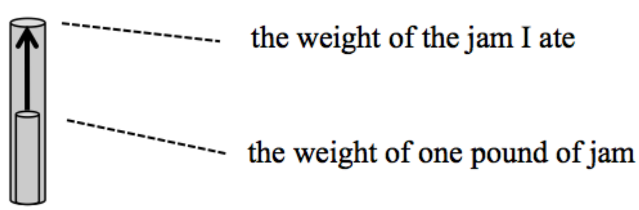
To see how this works in an intuitive way, consider the examples in (12).

(12) a. The picture is **over** the mantel.
b. I ate **over** a pound of jam.

In (12a), *over* expresses a vertical relation between two material objects in 3D space, as illustrated graphically with the upward arrow in the left-hand picture in (13) that points from the top of the mantel to the bottom of the figure. In (12b), *over* also expresses a vertical relation, but now between two abstract containers in 1D space. The smaller container represents the weight of one pound of jam, the taller container represents the weight of the jam that the subject ate, and the arrow represents the vertical relation between the two.

(13) *over the mantel* and *over a pound of jam* in (12)





We will now spell out our spatial assumptions in more detail first and then show how (abstract) containers behave in space.

3.1 Some spatial building blocks

For our purposes it is sufficient to make the following general (and simplified) assumptions about the spatial domain, that are necessary independent of the treatment of measure phrases.

In addition to the basic domain E of objects (type e) and truth values {0,1} (type t), we have the ontological domain P of spatial points (type p), endowed with the appropriate geometrical structure that allows these points to be related to each other in terms of distance and direction (see Zwarts and Winter 2000 for details of one particular formalization, in terms of vectors). The full spatial domain is three-dimensional, but there are two-dimensional and one-dimensional subspaces, e.g., horizontal planes and vertical lines, respectively, that maintain the essential geometrical structuring of distance and direction.

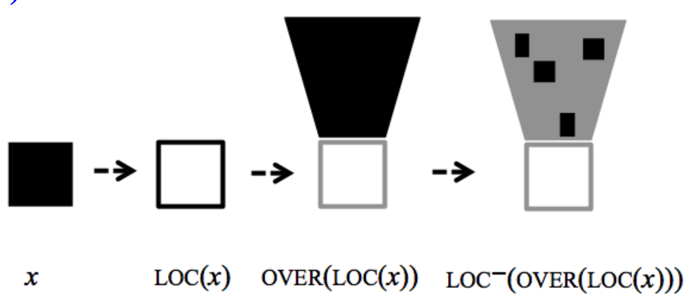
Any object that is located in space corresponds to a set of spatial points, its location in space ('eigenspace', Wunderlich 1991), that is topologically closed, i.e., includes its boundary. We assume a partial function LOC (type $\langle e,\langle p,t\rangle\rangle$) that maps an object to the set of points that constitutes its boundary. For instance, if THE(MANTEL) is a contextually unique mantel, then LOC(THE(MANTEL)) is its spatial boundary. It is through its spatial boundary that an object is spatially related to other objects and this is where locative prepositions come in.[4]

Every locative preposition can be interpreted as a function that takes a spatial boundary and maps it to a particular spatial region with respect to that boundary (type $\langle\langle p,t\rangle,\langle p,t\rangle\rangle$). For example, OVER maps the spatial boundary of the mantel, LOC(THE(MANTEL)), to the region of points that we find when going outward and upward from it. OVER(LOC(THE(MANTEL))) is then the spatial denotation (type $\langle p,t\rangle$) of the locative PP *over the mantel*.

In order to allow objects to be located in this region, that is, to be over the mantel, we map the region 'back' into the object domain, by assigning it those objects of which the boundary is a subset of OVER(LOC(THE(MANTEL))). This function that does this, LOC^{-}, turns a region-denoting PP (type $\langle p,t\rangle$) into a predicate of type $\langle e,t\rangle$. So, (14a) corresponds to the proposition that the painting is over the mantel, which amounts to the more transparent (14b), while figure (15) shows in a schematic way the different steps from a reference object x to the objects that are located over it.

(14) a. LOC^{-}(OVER(LOC(THE(MANTEL))))(THE(PAINTING))
b. LOC(THE(PAINTING)) $\subseteq$ OVER(LOC(THE(MANTEL)))

(15) From x to *over* x



3.2 Some assumptions about container semantics

Concrete containers, like baskets, bottles, and boxes, have at least three stereotypical properties that are important for understanding their fundamental role in the semantics of measures. First, they have a typical vertical orientation that allows them to fulfill their function: to contain substances like apples, ale, or ammunition. Second, a container

[4] We depart here from the usual view taking prepositions to operate with the eigenspace of an entity: it makes no difference that we can detect in the 3D space, but becomes crucial for the 1D space.

implies a rough volume unit: it maps different substances to more or less the same volume unit, if those substances completely fill the container. If we know that a particular bottle can hold 1 liter of water, then it can also hold 1 liter of beer. Third, the inside of a container has a bottom that corresponds to the zero level of its contents. As a result of these properties, we can already see how concrete containment involves a structure-preserving mapping of quantities to vertical positions.

Container nouns like *basket*, *bottle*, and *box* have a basic $\langle e,t\rangle$ denotation, just like other sortal nouns, but they can be shifted to a transitive type $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$, that allows them to combine with a substance NP of type $\langle e,t\rangle$[5] in the pseudo-partitive structure (Selkirk 1977), filling the containers with the substance. For instance, the pseudo-partitive nominal *jar of jam* denotes the set of jars that are filled with jam. Assuming that $\text{FILL}(s,c)$ represents that a sum or substance *s* completely fills a container *c*, we can define this type-shifting function CONT as in (16):

(16) For every set of containers C, $\text{CONT}(C) = \lambda S.\lambda x.\exists y\,[\,C(x)\ \&\ S(y)\ \&\ \text{FILL}(y,x)\,]$
e.g., $\text{CONT}(\text{JAR})(\text{JAM}) = \lambda x.\exists y\,[\,\text{JAR}(x)\ \&\ \text{JAM}(y)\ \&\ \text{FILL}(y,x)\,]$

At first blush this gives us what Partee and Borschev 2012 call the Container + Contents reading of the pseudo-partitive (“a container together with a substance that fills it”, see also Rothstein 2009a). However, if we look at how CONT is defined, we see that it ultimately defines a set of *containers*, backgrounding the contents to an existential quantifier. If we want to specifically refer to the contents, we need to extract them again, using the function in (17a), as in (17b):

(17) a. For every set of containers C, $\text{CONT}^{-}(C) = \lambda y.\exists x\,[\,C(x)\ \&\ \text{FILL}(y,x)\,]$
b. $\text{CONT}^{-}(\text{CONT}(\text{JAR})(\text{JAM})) = \lambda y.\exists x\,[\,\text{CONT}(\text{JAR})(\text{JAM})(x)\ \&\ \text{FILL}(y,x)\,]$

What we get then in (17b) is the set of substances that fill containers of jam.

All of these properties and operations carry over to what we call abstract containers: abstract objects that contain and thereby measure substances, like liters, pints, bushels, etc. Importantly, however, the abstractness of abstract containers implies that they differ in a number of properties from concrete containers. (1) Their dimensionality is reduced to just one dimension, which must then necessarily be the vertical dimension. (2) Due to this one-dimensionality there is no distinction between the material ‘shell’ of the container and the non-material inside: an abstract container is nothing but (one-dimensional, vertically oriented) ‘inside’. (3) Abstract containers all have their bottom in the zero point of the vertical dimension (the ‘ground’; cf. Nouwen 2016), but they differ in height. (4) Unlike concrete containers, abstract containers can be stacked to form new containers. A liter can be stacked on top of another liter, giving an abstract container measuring two liters. A pint can be stacked on top of a gallon. (5) Because of their reduced nature, abstract containers that have the same base and height are indistinguishable. Two one liter containers are indistinguishable unless stacked (because then they have different bases).

The notion of an abstract measuring container needs to be generalized beyond volumes to include all quantities, like weight, length, etc. The kilogram and the yard are also abstract containers, for instance. Obviously, liters, kilograms, and yards are incommensurable, and they cannot live in the same one-dimensional space. We must distinguish volume space from weight space, length space, etc., as different instantiations of one and the same vertically oriented 1D space. We stipulate this restriction for now,

[5] A reasonable alternative is that the substance NP is kind-denoting – a hypothesis that is supported by the fact (Klooster 1972) that in Dutch the substance NP cannot be modified by a relative clause (for English see Duek and Brasoveanu 2015). We will not explore this alternative here as orthogonal to our purposes.

taking it to be a result of the way measuring a particular quality of a multi-dimensional object involves 'projecting' that object on one particular dimension.

Another aspect of this impoverishment is that the bottom of one abstract container always coincides with the ground (zero) level of the vertical space (unless stacked on top of another container). As a result, the only relevant boundary of such a non-stacked container is just its spatial top: LOC(*c*) is a singleton with just that top as its element. Containers are related to each other in 1D space through their tops. For instance, OVER(LOC(*c*)) is the set of points in 1D space that are higher than the top of *c*, UNDER(LOC(*c*)) is the set of points lower than the top of *c*, and AROUND(LOC(*c*)) is the set of points close to the top of *c*. If we now apply LOC^{-}, we get (18):

(18) LOC^{-}(OVER(LOC(*c*))) = the set of abstract containers whose top is higher than the top of *c*
LOC^{-}(UNDER(LOC(*c*))) = the set of abstract containers whose top is lower than the top of *c*
LOC^{-}(AROUND(LOC(*c*))) = the set of abstract containers whose top is close to the top of *c*

When two containers are stacked, then the bottom of one container coincides with the top of the container that it is stacked on. Given that a 1D space can only host containers of the same quality (volume, weight, length, ...), the available spatial operators gives us a spatial ordering of abstract containers of a particular quality.

3.3 Towards a compositional interpretation

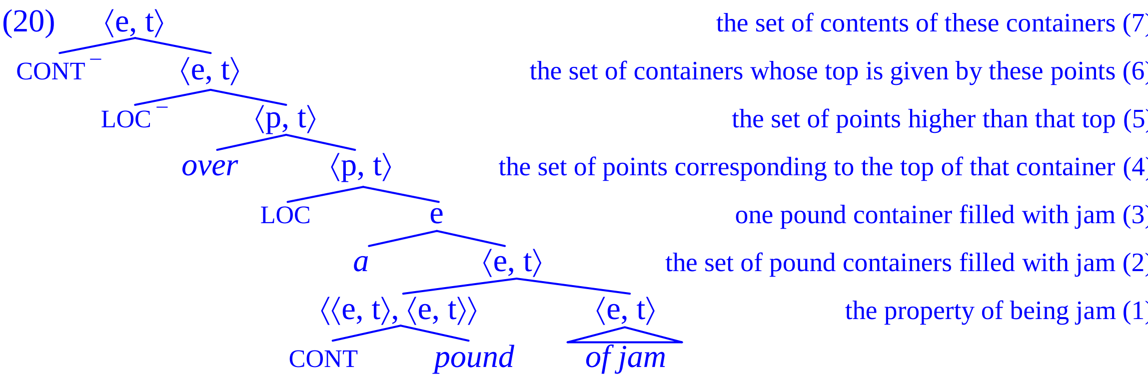
Given these building blocks, let us now try to piece together how the phrase *over a pound of jam* receives its interpretation in a compositional way. We want this phrase to denote a set of quantities of jam, in line with its predicative use in (19a) and (after the application of an invisible existential quantifier) its argument use in (19b).

(19) a. Less than a pound of strawberries can easily become **over a pound of jam**.
b. I was given **over a pound of jam**.

More specifically, we would like it to denote the set of jam-filled volume containers with a top higher than the top of the abstract pound container filled with jam.

(1) We start with *pound*, denoting the set POUND of abstract containers that measure that volume unit and that are part of the vertical volume space. The elements of this set are indistinguishable from each other. (2) After CONT covertly applies to POUND, we get the transitive version CONT(POUND) of *pound*,[6] that can apply to a complement denoting a substance, like *jam*. (3) The pseudo-partitive combination *pound of jam* is interpreted as CONT(POUND)(JAM), which is the set of pound containers filled with jam. The indefinite article applies: A(CONT(POUND)(JAM)). For simplicity's sake we assume that A is a choice function of type ⟨⟨e,t⟩,e⟩ (Reinhart 1992, 1997) picking out an element from this set. (4) We then covertly map this single container to its region in the vertical volume space, which is a singleton containing only the top of that container. (5) Now the preposition *over* can apply, mapping the top region of the container to the region of spatial points above it, OVER(LOC(A(CONT(POUND)(JAM)))). (6) LOC^{-} then covertly maps this region to the set of containers that have their top in that region, i.e. that are higher than the single pound of jam. (7) CONT^{-} finally gives us the contents of these containers.

[6] For the sake of simplicity we represent CONT structurally, without, however, committing ourselves to this particular syntax: CONT could be a structurally neutral type-shifting operation. Alternatively, measure nouns like *pound* are already transitive, in which case CONT is not necessary here.

(20) 

The problem is that all by itself (20) does not yet give us the set of *jam* portions that weigh more than a pound, which is what *over a pound of jam* should denote.[7] We have a phrase that denotes the set of portions of matter filling containers whose weight is over one pound, but there is no guarantee that these are portions of jam. The information about the content of the containers is in a sense 'lost' in the compositional process when the jam-filled pound container is mapped into space. How can we get jam 'back' into all the containers? At the moment we see two types of solutions. One solution is to assume that the 1D space underlying (20) is homogeneously associated with one substance only, namely jam. Every container in this space ontologically inherits this contents from the filling of the initial pound container. The compositionally more explicit solution we choose is to move the phrase *of jam* and adjoin it to the PP after CONT⁻ has applied.[8] Whether *of jam* is also applied in its base position is irrelevant (we assume that it does, for simplicity). Important is that it is at least interpreted in the landing position, using predicate modification (Heim and Kratzer 1998), which boils down to intersection of the two sister denotations:

(21) CONT⁻(LOC⁻(OVER(LOC(A(CONT(POUND)(JAM)))))) ∩ JAM

The whole compositional derivation with movement is summarized in the tree in (22).

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[7] Which makes PP-pseudo-partitives different from the comparative *more than a pound of jam*, which can denote a quantity of something with a larger amount than the quantity of a pound of jam (see Ionin and Matushansky 2013, Matushansky and Ionin 2014 for a discussion).

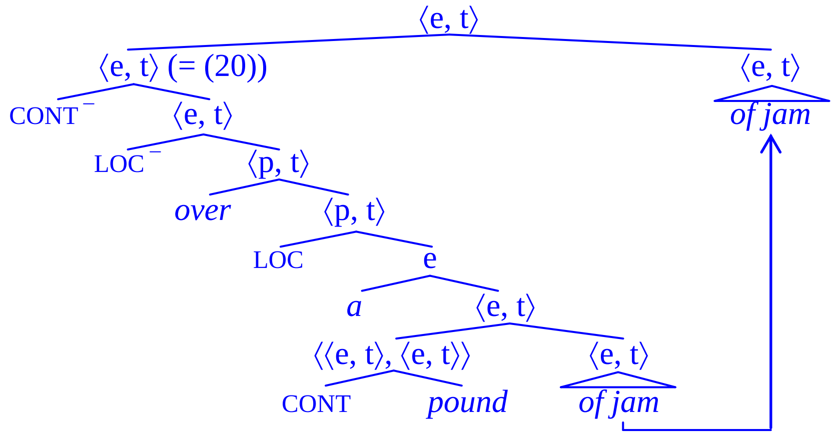
[8] Some evidence for such an approach comes from Basque. Being head-final, Basque makes it possible to diagnose right-extraposition of the substance NP by its surface position to the right of the postposition in a measure PP:

(i) bost kilo patata-tik gora — Basque, Ane Berro, p.c.
five kilo potato-ABL up.ALL
over five kilos of potatoes

(ii) bost kilo-tik gora patata
five kilo-ABL up.ALL potato
over five kilos of potatoes

While in a regular locative PP the postposition is final, in a measure PP the substance NP is preferably found in the right periphery of the PP (see Matushansky et al. 2017), strongly suggesting extraposition, as predicted by our analysis. Note that Basque word order also offers evidence against treating as a constituent either the preposition and the cardinal (which form a discontinuous string in Basque) or the preposition and the measure phrase (which may be separated by the substance NP, as in (i)).

(22)



The interpretation of this movement structure is unusual, because it does not involve lambda-abstraction over the trace left by *of jam*, as commonly assumed. If it did, then the left-hand daughter of (22) would have the denotation in (23), which, when applied to its sister's denotation, would yield the same result as (20), making the movement vacuous, as is usual for movement of predicates (Heim and Kratzer 1998), but incorrect for our purposes.

(23) λP.CONT⁻(LOC⁻(OVER(LOC(A(CONT(POUND)(P))))))

Assuming that *of jam* is interpreted as an argument in its original position and as a modifier in its derived position solves this problem without presenting others, although the semantic status of this type of movement requires further scrutiny.

3.4 External syntax of prepositional measures

Starting NP-internally, the predicative denotation of prepositional measures correctly allows them to semantically compose with determiners (24).

(24) a. **the [over 9 million liters of water** and 50,000 filters distributed by FEMA][9]
b. for the duration of **those up to ten minutes**[10]

Yet PPs generally being incompatible with determiners, the question arises whether the prepositional measure phrase is syntactically an NP, which can be achieved either by treating CONT⁻ as a covert head with nominal features, or by introducing such a head above the landing site of the substance NP. We believe, however, that this is an incorrect move, given that the number and gender specification of the article combining with a measure PP cannot be formally established. To see this, consider examples like (25)-(26), where the measure noun and the substance noun both are singular and have gender. Ineffability is due to the need to establish the gender of the determiner, as shown by (27), where the plural article is syncretic with the plural (27a) or the common gender (27b) of the substance NP. Had a nominalizing head been present, it would have introduced its own gender and number features, and the ineffability would have been unexpected.

(25) a. *het rond een pond meel dat ik gekocht heb — Dutch
DEF.NSG around a pound$_N$ flour$_N$ that$_N$ I bought have

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[9] https://www.whitehouse.gov/the-press-office/2016/05/03/fact-sheet-federal-support-flint-water-crisis-response-and-recovery

[10] https://cathyjf.com/articles/effect-of-capitalisation

b. *de rond een pond meel die ik gekocht heb
DEF.PL/DEF.CSG around a pound$_{N}$ flour$_{N}$ that$_{PL/CSG}$ I bought have
the around a pound of flour that I bought

(26) *èti/*ètot/*èta okolo litra vody — Russian
this.PL/MSG/FSG around liter$_{M}$.GEN water$_{F}$.GEN
??*these over a liter of water*

(27) a. de rond een pond aardappeltjes die ik gekocht heb
DEF.PL around a pound$_{N}$ potatoes$_{PL}$ that$_{PL}$ I bought have
the around a pound of potatoes that I bought

b. de rond een kilo cocaïne die ik gekocht heb
DEF.PL around a kilogram$_{CSG}$ cocaine$_{CSG}$ that$_{PL}$ I bought have
the around a kilogram of cocaine that I bought

Taking it for granted that prepositional measures have the external distribution of NPs it comes as no surprise that in prepositional measures we can have not only the indefinite article, but also numerals (28a,c,d,e), and that a prepositional measure can occur in every position where we can find a measure phrase, as the object of a measure verb (28b), a predicate (28c), a differential (28d), and a PP modifier (28e):

(28) a. **Over 5 inches of snow** could fall on Sunday.
b. The spaceship weighed well **under a ton** thanks to antigravity.
c. The rate is already **below 7%**.
d. The wait can be [**between two and three hours] longer** than anticipated.
e. The body was found [**around five meters] behind the house**.

Because we treat measure nouns as nouns, their ability to combine with cardinals in their standard interpretation is expected, and from the semantic standpoint no difference in the distribution of NP measures and PP measures is anticipated. To take one example, we can easily show that a prepositional measure like *under five liters* can be interpreted with the semantics provided above, in combination with the cardinal semantics of Ionin and Matushansky 2006.[11] The noun *liter* refers to the set of one liter containers. After application of the cardinal we have the phrase *five liters* denoting the set of sums that can each be partitioned into five one-liter containers. Given the nature of these containers and the 1D space they live in, a sum of five containers is actually a stack of five containers, which can in turn be taken as one five-liter container. After a covert choice function picks an element from this set of five-liter containers, LOC can map this container to its top. Then *under* can apply, yielding the set of points lower than this top. LOC^{-} then converts the spatial denotation back to the set of containers of which the top is located in this spatial denotation.

(29) a. under five liters
b. [LOC^{-} [under [LOC [~~a~~ [five liters]]]]]
c. 'the set of volume containers of which the top coincides with a point that is lower than the top of a stack of five one-liter containers'

An intransitive measure expression like in (29) can be the object of a transitive measure verb like *weigh* that establishes a relation between the 3D entity denoted by the subject and the 1D measure denoted by the object. The semantics of such measure verbs

[11] The standard intersective semantics of cardinals (Landman 2003, etc.) would do just as well here.

remains to be worked out, either more concretely (with the subject denotation 'filling' the abstract measure) or more abstractly (with the object denotation being the 'projection' of the subject denotation on a particular 1D space). Its use as a non-verbal predicate (cf. Lasersohn 2003), as in (28c), gives rise to the same projection vs. filling issue, whereas in its use as a differential (28d) or as a PP modifier (28e) it can be taken as the modifier of the one-dimensional distance in the abstract space determined by the semantics of the AP or PP respectively; space reasons prevent us from addressing this matter in detail.

Another issue that must remain as a topic for future research is the compositional semantics of measure prepositions in the absence of a measure noun, as in (1a). Here also the composition of 1D spaces becomes relevant, or the same syntactic movement solution can be advanced. Given that these structures do not appear to raise any new problems, we save space by not discussing it any further here.

4. Conclusion

The core of our proposal lies in postulating abstract spaces with reduced (1D) structure. Independent evidence for such spaces comes from other instances of the spatial metaphor (Lakoff 1993), such as the use of prepositions with resultatives (*change a princess into a frog*) and result states (*loving me to death/into an early grave*). The consequences of this proposal are manifold and include the standard entity-based type for measure nouns, with no change in the semantics of prepositions, whose choice can now be derived from one-dimensionality and inherent verticality. More importantly, this proposal supports, to our mind, an independently motivated implementation of scalar structure as spatial structure (cf. Faller 1998, 2000, Winter 2005, and for a wider perspective Gärdenfors 2004, 2014), leading to eventual elimination of degrees or scales from the semantic ontology.

5. Bibliography

Bateman, John A., Joana Hois, Robert Ross, and Thora Tenbrink. 2010. A linguistic ontology of space for natural language processing. *Artificial Intelligence* 174, pp. 1027-1071.

Blok, Dominique. 2013. Directional prepositions as numeral modifiers, MA thesis: Utrecht University.

Blok, Dominique. 2016. The semantics and pragmatics of directional numeral modifiers. *2016*, pp. 20.

Blok, Dominique. [to appear]. Directional numeral modifiers: an implicature-based account. In *Proceedings of NELS 46*, ed. by Christopher Hammerly and Brandon Prickett. Amherst, Massachusetts: GLSA.

Borer, Hagit. 1999. Deconstructing the construct. In *Beyond Principles and Parameters*, ed. by Kyle Johnson and Ian Roberts, pp. 43-90. Dordrecht: Kluwer.

Borer, Hagit. 2005. *In Name Only*. Structuring Sense 1. Oxford: Oxford University Press.

Corver, Norbert, and Joost Zwarts. 2006. Prepositional numerals. *Lingua* 116, pp. 811-835.

Cresswell, M. J. 1976. The semantics of degree. In *Montague Grammar*, ed. by Barbara H. Partee, pp. 261-292. New York: Academic Press.

Duek, Karen, and Adrian Brasoveanu. 2015. The polysemy of container pseudo-partitives. In *Proceedings of Sinn und Bedeutung 19*, ed. by Eva Csipak and Hedde Zeijlstra, pp. 214-231.

Faller, Martina. 1998. A vector space semantics for dimensional adjectives. In *Proceedings of ESSLLI 1998*.

Faller, Martina. 2000. Dimensional adjectives and measure phrases in vector space semantics. In *Formalizing the Dynamics of Information*, ed. by Martina Faller, Stefan Kaufmann and Marc Pauly. Stanford: CSLI.

Gärdenfors, Peter. 2004. *Conceptual Spaces: The Geometry of Thought*: MIT Press.

Gärdenfors, Peter. 2014. *The Geometry of Meaning: Semantics Based on Conceptual Spaces*: MIT Press.

Gawron, Jean Mark. 2002. Two kinds of quantizers in DP. Paper presented at *LSA Annual Meeting*

Grimshaw, Jane. 2007. Boxes and piles and what's in them: two extended projections or one. In *Architectures, Rules and Preferences: A Festschrift for Joan Bresnan*, ed. by Annie Zaenen, Jane Grimshaw, Joan Maling, Christopher D. Manning and Jane Simpson, pp. 245-252. Stanford, California: CSLI.

Heim, Irene. 1985. Notes on comparatives and related matters. Ms., University of Texas, Austin.

Heim, Irene, and Angelika Kratzer. 1998. *Semantics in Generative Grammar*. Oxford: Blackwell.

Ionin, Tania, and Ora Matushansky. 2006. The composition of complex cardinals. *Journal of Semantics* 23, pp. 315-360.

Ionin, Tania, and Ora Matushansky. 2013. More than one comparative in more than one Slavic language: an experimental investigation. In *Formal Approaches to Slavic Linguistics #21: The Third Indiana Meeting*, ed. by Steven Franks, Markus Dickinson, George Fowler, Melissa Whitcombe and Ksenia Zenon, pp. 91-107. Ann Arbor, Michigan: Michigan Slavic Publications.

Kennedy, Christopher. 1999. *Projecting the adjective. The syntax and semantics of gradability and comparison*. New York: Garland.

Klooster, Wim. 1972. *The Structure Underlying Measure Phrase Sentences*. Dordrecht: Reidel.

Kracht, Marcus. 2002. On the semantics of locatives. *Linguistics and Philosophy* 25, pp. 157-232.

Lakoff, George. 1993. The contemporary theory of metaphor. In *Metaphor and Thought*, ed. by Andrew Ortony, pp. 202-251. Cambridge: Cambridge University Press.

Lakoff, George, and Mark Johnson. 1980. *Metaphors We Live by*. Chicago: University of Chicago Press.

Lakoff, George, and Rafael Núñez. 2000. *Where Mathematics Comes from: How the Embodied Mind Brings Mathematics Into Being*: Basic Books.

Landman, Fred. 2003. Predicate-argument mismatches and the adjectival theory of indefinites. In *From NP to DP. Volume I: The Syntax and Semantics of Noun Phrases*, ed. by Martine Coene and Yves D'hulst. *Linguistics Today*, pp. 211-237. Amsterdam and Philadelphia: John Benjamins.

Landman, Fred. 2004. *Indefinites and the Type of Sets*. Oxford: Blackwell.

Landman, Fred. 2015. Iceberg semantics for mass nouns and count nouns. Ms., Tel-Aviv University.

Lasersohn, Peter. 2003. The temperature paradox as evidence for a presuppositional analysis of definite descriptions. Ms., University of Illinois.

Lehrer, Adrienne. 1986. English classifier constructions. *Lingua* 68, pp. 109-148.

Matushansky, Ora, and Tania Ionin. 2014. More than one solution. In *Proceedings of CLS 47*, ed. by Carissa Abrego-Collier, Arum Kang, Martina Martinovic and Chieu Nguyen, pp. 231-245. Chicago: Chicago Linguistic Society, University of Chicago.

Matushansky, Ora, E. G. Ruys, and Joost Zwarts. 2017. On the structure and composition of pseudo-partitives. Paper presented at *Séminaire LaGraM*, UMR 7023, Paris, January 16, 2017.

Nouwen, Rick. 2008. Directionality in modified numerals: the case of *up to*. In *Proceedings of Semantics and Linguistic Theory (SALT) 18*, ed. by Tova Friedman and Satoshi Ito, pp. 569-582: eLanguage.

Nouwen, Rick. 2010. Two kinds of modified numerals. *Semantics and Pragmatics* 3, pp. 1-41.

Nouwen, Rick. 2016. Making sense of the spatial methaphor for number in natural language. Ms., Utrecht University.

Partee, Barbara H., and Vladimir Borschev. 2012. Sortal, relational, and functional interpretations of nouns and Russian container constructions. *Journal of Semantics* 29, pp. 445-486.

Plank, Frans. 2004. From local adpositions to approximative adnumerals, in German and wherever. *Studies in Language* 28, pp. 165-201.

Reinhart, Tanya. 1992. Wh-in-situ: An apparent paradox. In *Proceedings of the Eighth Amsterdam Colloquium*, ed. by Paul Dekker and Martin Stokhof, pp. 483–492. Amsterdam: ILLC, University of Amsterdam.

Reinhart, Tanya. 1997. Quantifier scope: How labor is divided between QR and choice functions. *Linguistics and Philosophy* 20, pp. 335-397.

Ritter, Elisabeth. 1987. NSO noun phrase in Modern Hebrew. In *Proceedings of NELS 17,* ed. by Joyce McDonough and Bernadette Plunkett, pp. 521-537. Amherst, Massachusetts: University of Massachusetts, GLSA.

Ritter, Elisabeth. 1988. A head-movement approach to construct-state noun phrases. *Linguistics* 26, pp. 909-929.

Rothstein, Susan. 2009a. Individuating and measure readings of classified constructions: evidence from modern Hebrew. *Brill's Annual of Afroasiatic Languages and Linguistics* 1, pp. 106-145.

Rothstein, Susan. 2009b. Towards a grammar of counting and measuring. Paper presented at *Workshop on nominal and verbal plurality*, Paris, France, November 6-7, 2009.

Rothstein, Susan. 2011a. Counting, measuring and the semantics of classifiers. In *The Baltic International Yearbook of Condition, Logic and Communication*, vol. 6, ed. by Barbara Partee, Michael Glanzberg and Jurģis Šķilters, pp. 1-42. Manhattan, Kansas: New Prairie Press.

Rothstein, Susan. 2011b. Numbers: counting, measuring and classifying. Paper presented at *Sinn und Bedeutung 16*, Utrecht University, September 6-9, 2011.

Ruys, E.G. 2017. Two Dutch *many*'s and the structure of pseudo-partitives. *Glossa* 2, pp. 7-33.

Schwarz, Bernhard, Brian Buccola, and Michael Hamilton. 2012. Two types of class B numeral modifiers: A reply to Nouwen 2010. *Semantics and Pragmatics* 5, pp. 1-25.

Selkirk, Elisabeth. 1977. Some remarks on noun phrase structure. In *Formal Syntax*, ed. by Peter W. Culicover, Thomas Wasow and Adrian Akmajian, pp. 285-316. London: Academic Press.

Seuren, Pieter A. M. 1973. The comparative. In *Generative Grammar in Europe*, ed. by Ferenc Kiefer and Nicolas Ruwet, pp. 528-564. Dordrecht: D. Reidel.

van Gestel, Frank. 1986. *X-bar Grammar: Attribution and Predication in Dutch*. Dordrecht: Foris.

Vos, Riet. 1999. A Grammar of Partitive Constructions, Doctoral dissertation, Tilburg University.

Winter, Yoad. 2005. Cross-categorial restrictions on measure phrase modification *Linguistics and Philosophy* 28, pp. 233-267.

Wunderlich, Dieter. 1991. How do prepositional phrases fit into compositional syntax and semantics? *Linguistics* 29, pp. 591-622.

Zwarts, Joost, and Yoad Winter. 2000. Vector space semantics: a model-theoretic analysis of locative prepositions. *Journal of Logic, Language and Information* 9, pp. 169-211.