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MAKING SPACE FOR MEASURES

Our twin goals in this paper are to provide a compositional analysis of prepositional measures as in (1) and to advance a general hypothesis on the nature of measures (degrees) that would root them in the more familiar ontology of entities and spaces.

(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. She just got married for **under a hundred dollars**.
     d. The distance was somewhere **between a kilometer and a mile**.

Syntax: As the compatibility of spatial prepositions with indefinite measures (1b,d) shows, it is impossible to assume, as Corver and Zwarts 2006 did, that the preposition combines with the cardinal before merging with the rest of the pseudo-partitive. We assume with Klooster 1972, Selkirk 1977, Lehrer 1986, Vos 1999, Grimshaw 2007, Landman 2015, etc. (and contra Gawron 2002, Rothstein 2009a, b, 2011a, b, etc.), that the measure noun is the head of the pseudo-partitive (evidence for this will be provided from agreement and case-marking, but the issue of composing a pseudo-partitive with a spatial preposition arises for all approaches).

Semantics: It seems obvious that the compositional semantics of prepositional measures does not involve locating an entity in normal space (as in the slightly aberrant interpretation of (1b), where not jam is eaten, but something around it). The question therefore arises if it is the interpretation of the spatial prepositions that should change or that of the pseudo-partitive.

Proposal: We suggest a novel approach to measure nouns such as *pound* or *kilometer*, which allows the spatial prepositions in (1) to perform the same locating function that they usually perform (e.g., *over/around/under the table*). Specifically, we propose to treat measure nouns as **abstract containers**. This is conceptually driven by the role that the notion of a container plays in the cognitive foundation of our mathematical faculty (Lakoff and Núñez 2000), underlying our reasoning with sets and quantities, and empirically motivated by the centrality of container nouns (like *glass*) in the pseudo-partitive construction and by the simultaneous availability of container and content interpretations there (Selkirk 1977, Landman 2004, Grimshaw 2007, Rothstein 2009a, Partee and Borschev 2012, Duek and Brasoveanu 2015, etc.), as well as by the historical development of many measure terms out of container nouns (e.g., *cup*, *barrel*). We propose therefore that, like the interpretation of the NP *a glass of wine* involves a concrete container (glass) filled to a sufficient level with a substance (wine), the interpretation of *a pound of jam* involves an abstract container, corresponding to the pound unit, filled with jam substance. Just as glasses may be empty, so can pounds, yielding the intransitive use of measure nouns, as in *The engine weighs three hundred pounds*.

Abstract containers: While a glass is a three-dimensional container with a material enclosure of an interior, we propose that measure nouns denote one-dimensional containers located in a vertically oriented half-open one-dimensional space; the relative magnitude of the measure (*ounce* vs. *pound*) with respect to the relevant dimension (weight) is reflected by the height of the container. One immediate consequence of this approach is that the algebra of measures directly follows from the independently motivated properties of one-dimensional space. Indeed, in a one-dimensional space with a natural zero (ground), there are only two ways of relating abstract containers, as long as levitation is disallowed: **superposition** (the bottom of both containers is at zero) and **stacking** (the bottom of one container is on top of the other). Superposition gives us the indistinguishability of two instances of the same measure with respect to each other: there is no space to separate them and thus to distinguish. Conversely, stacking, i.e., the placement of two containers one on top of the other, gives us the operation of **concatenation**, naturally deriving addition for two distinct measures (e.g., *one pound one ounce*) and multiplication (*two pounds*) for two identical ones.

Spatial prepositions: Assuming that measure nouns denote one-dimensional containers located in one-dimensional space also permits prepositions to function in the usual way. We predict that any preposition that can describe a vertical relation between entities in real space would also work on a measure conceived in this way. This prediction seems to be correct:

while vertical prepositions like *above*, *below*, *under*, and *over*, and neutral prepositions like *around*, *about* and *between* are allowed, those that are restricted to the horizontal plane (*behind*, *beside*, *in front of*, *next to*, *left*, *right*) are not. The topological prepositions (*in*, *on*, *at*) are not expected, as they operate in three dimensions, while directional prepositions (*from*, *to*), which do not, are in fact attested (see also Nouwen 2008).

Formalization: to capture this, we will treat abstract containers as upward-pointing spatial vectors. The desired properties follow immediately, as two vectors are distinguished by their direction and length, but not the point of origin. Concatenation in this framework naturally corresponds to vector addition (**pound**+**ounce**), deriving scalar multiplication (=2**pound**) compositionally if the partition-based semantics of cardinals by Ionin and Matushansky 2006 (rather than the more common cardinality-based approaches) is assumed. As a further result, this gives us a scale (of weights, for *pound*), drawing on the underlying ontology of space.

Following now and somewhat simplifying Zwarts and Winter 2000, suppose that the relevant prepositions are defined as relations between vectors u and v (representing positions in one and the same space), where a vector w of a particular direction (**up**, **down**) or length (**short**) is added to vector u to give us vector v:

(2)   a. $[\![over]\!] = \lambda u.\lambda v.\exists w\ [\ v=u+w\ \&\ \textbf{up}(w)\ ]$
       b. $[\![around]\!] = \lambda u.\lambda v.\exists w\ [v=u+w\ \&\ \textbf{short}(w)\ ]$
       c. $[\![under]\!] = \lambda u.\lambda v.\exists w\ [\ v=u+w\ \&\ \textbf{down}(w)\ ]$
       d. $[\![between]\!] = \lambda u_1 u_2.\lambda v.\exists w\ [\ v=u_1+w\ \&\ w$ points in the direction of $u_2\ ]$

Concrete containers: Turning now to regular containers, such as *glass*, we observe that they can also combine with spatial prepositions (1a), but only if viewed as having more or less the same (not necessarily standard) measure (cf. Partee and Borschev 2012). As nothing prevents the re-conceptualization of concrete containers as abstract ones, we hypothesize that a two-way mapping between the two domains is available, permitting incidentally also the mapping of less standard containers, such as *a bag of books*; the English suffix *-ful* may be taken as an overt reflex of this mapping. An illustration of this mapping in the opposite direction, from standard measure nouns to containers of the relevant capacity, is given by Dutch (3), with the concrete container reading making available the plural marking on *liter* in (3b), which is otherwise impossible on standard measure nouns inside numeral NPs (Klooster 1972).

(3)   a.   drie   liter   water
            three   liter   water
            three liters of water

       b.   drie   liter-s   water
            three   liter-PL   water
            three liter-packs of water

What space is made of: The representation of measures as abstract containers has one more welcome property: the only way a one-dimensional container can be filled with a substance is if the entire one-dimensional space is made of that substance. As a result, the denotation of *a pound of jam* in this framework is simultaneously a pound and jam, by virtue of the system itself, yielding the simultaneous accessibility of both denotations. Better still, the same is true for *a glass of wine* without the need to postulate two different structures (Rothstein 2009a, b, 2011a, b, a.o.) or a dot-object (Duek and Brasoveanu 2015). It furthermore follows that the prepositional measure in (1a) denotes wine, to the absence of the additional interpretation of 'wine and something else', available for *more than five glasses of wine* (see Matushansky and Ionin 2014).

Additional points: We will argue that measure phrases in APs (e.g., *around two miles long*) are also represented as one-dimensional containers, providing evidence from the fact that measure phrases are allowed primarily with temporal and unidimensional spatial adjectives (Murphy 1997); others are much rarer. The question therefore arises of whether it is desirable to recast standard approaches to scalarity in spatial terms, thereby eliminating degrees from the ontology. We will finally discuss the application of the framework to numerals.