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Measurement in NP: Schwarzschild's 'Grammar of Measurement'

1 Some business

- Emails
- Wednesday, October 22 → Monday, October 20?

2 Measure phrases

2.1 Some distributional facts

Measure phrases (MPs) can combine with constituents headed by a variety of different syntactic categories:

(1) a. The plant is 17 inches high.
b. The plant is 5 inches taller than Pug.
c. The plant grew 5 inches overnight.
d. The top of the plant is 17 inches below the ceiling.
e. We need a 17 inch plant.
f. Bugs covered 4 inches of the plant's stem.

There are restrictions on the use of MPs, though:

(2) a. ??The plant is 2 months high.
b. ??The plant is 17 inches old.
c. ??The plant grew 2 months.

(3) a. The plant is two flowerpots high.
b. The plant is 60 revolutions of the earth old.
c. The plant grew twice its original height.

(4) a. The airplane is 5000m high/??low.
b. This airplane is 5000m higher/lower than that one.
c. The airplane is 2 years old/??young.
d. This airplaine is 2 years older/younger than that one.

(5) a. ??This rock is 30 ounces heavy/light.
b. This rock is 30 ounces heavier/lighter than that one.
c. This rock has a weight of 30 ounces.

(6) a. The E-string is 15 Hz sharp/flat.
b. Kim arrived 10 minutes early/late.

Schwarzschild (2002) observes some particularly interesting the differences in distribution and interpretation of MPs in NP:

(7) a. I need 2 ft^3 of dirt.
b. ??I need some 2 ft^3 dirt.

(8) a. ??I need 17 inches of flowering plant.
b. I need a 17 inch flowering plant.

(9) a. ??I need 30 degrees of water.
b. I need some 30 degree water.

(10) a. ??I need six feet of shovel.
b. I need a six foot shovel.

(11) a. This is too much gold.
b. too heavy, too great a volume
c. *too dark, too hot

2.2 Questions

1. Can we build a compositional semantics for measure phrases that explains their appearance in the variety of syntactic/semantic contexts in (1)?

2. What does the distribution and interpretation of MPs in different contexts (especially in NP) tell us about the grammar of measurement?

3 The semantics of MPs

3.1 Scalar intervals

Taking the use of MPs with gradable adjectives and directional prepositions as the starting point, Schwarzschild (2002) analyzes MPs as predicates of degrees (scalar intervals).

(12) a. \$2 more expensive, 2 lbs. too heavy, 2 feet away, 2 degrees below zero
b. that much faster, much too spicy, that much above the house

(13) $[\![\text{MP}]\!](d) = 1$ iff d measures MP-much

Some background assumptions:

1. Gradable adjectives (and locational prepositions?) denote measure functions: functions from objects to degrees (abstract representations of measurement).

2. Degrees are scalar intervals.

In this system, comparatives denote relations between degrees. (14b) represents the truth conditions of a standard comparative, but it won't work for differential comparatives (with MPs) like (15a-b).

(14) a. x is A-er than y
b. $\mathbf{A}(x) > \mathbf{A}(y)$

(15) a. Rod A is 2 inches longer than rod B (is).

b. Rod B is 2 inches shorter than rod A (is).

To handle these, we need to introduce a degree difference operation along the lines of (17); we can then analyze differential comparatives as in (17b).

(16) $d_1 - d_2 = max\{d \mid d \subseteq d_1 \wedge d \cap d_2 = \emptyset\}$

a. x is MP A-er than y
b. $[\![\text{MP}]\!](\mathbf{A}(x) - \mathbf{A}(y))$

(17) a. $[\![\text{2 inches}]\!](\mathbf{long}(A) - \mathbf{long}(B))$
b. $[\![\text{2 inches}]\!](\mathbf{short}(B) - \mathbf{short}(A))$

(18) a. LENGTH: 0 $\bullet$——— $\mathbf{long}(A)$ ———$\bullet$——— $\mathbf{short}(A)$ ———$\rightarrow\infty$
b. LENGTH: 0 $\bullet$—— $\mathbf{long}(B)$ ——$\bullet$——— $\mathbf{short}(B)$ ———$\rightarrow\infty$
c. $\mathbf{long}(A) - \mathbf{long}(B) =$ $\bullet$—$\bullet$
d. $\mathbf{short}(B) - \mathbf{short}(A) =$ $\bullet$—$\bullet$

What about the 'positive' form? This is actually pretty straightforward:

(19) a. Rod A is 2 inches long.
b. $[\![\text{2 inches}]\!](\mathbf{long}(A))$

This seems like a promising analysis (though we'll consider a potential wrinkle below), but ideally we'd like a fully compositional semantics for MPs, and in particular, one that makes some progress towards handling some of the facts we discussed above. (Whether we want one that's 'nominalistic' is a question I'll leave aside; see Parsons 1970.)

Here is one way we might go about doing things:

1. Relate 'unit nominals' to measurements of appropriate 'standards' (the official meter stick in Paris, the distance that light travels in one year, etc.).
2. Introduce an appropriate measure function into the meaning of the nominal to associate it with the right scale.
3. Assume basically the same structure over units of measurement (degrees) that we assume for 'regular' countable objects.

First (for reasons that will become clear below), let us assume that unit nominals presuppose that their degree arguments come from the scales over which their units are defined:

(20) $[\![\text{meter}]\!] = \lambda d : d \in Dom(\mathbf{long}).d = \mathbf{long}(m)$ $\qquad$ m = the Paris meter stick

We can now analyze 'counted measures' in the same way that e.g. Link 1983 analyzes 'counted objects' (here * actually corresponds to Link's *proper plural* operator, which eliminates atoms from the extension of the predicate).

(21) a. $[\![\text{meters}]\!] = {}^*[\![\text{meter}]\!] = \lambda d.d$ *is an i-sum of meter-length degrees*
b. $[\![\text{two}]\!] = \lambda P \lambda d.{}^*P(d) \wedge d$ *consists of (at least) 2 atoms*
c. $[\![\text{two meters}]\!] = \lambda d.{}^*[\![meter]\!](d) \wedge d$ *consists of (at least) 2 atoms*

This still needs some work. In particular, the assumption that degree atoms are just like individual atoms is a bit problematic. We need to deal with degree overlap — either by assuming that the join operation on degrees is the concatenation operation, or by adding some sort of discreteness to the scale. (Suggestions?)

However, something like this can probably be made to work. A good initial result is that the assumption that unit nominals in MPs contain a measure function will take care of some of the distributional facts we obseved above.

Specifically, the functions denoted by measure phrases are defined only for:

1. degrees on particular scales (determined by the head of the MP) and
2. degrees with a particular structure (positive degrees) (cf. von Stechow 1984).

The first condition will handle cases like (22a). The presupposition imposed by the unit nominal *month* is that its degree argument must be a degree of temporal extent, but the adjective *tall* returns degrees of linear extent.

(22) a. ??Julian is 15 months tall.
b. $[\![\text{15 months}]\!]\mathbf{tall}(j)$

(23) $[\![\text{month}]\!] = \lambda d : d \in Dom(\textbf{t-extent}).d = \textbf{t-extent}(m)$

To the extent that we can make sense of this, we need to reanalyze *month* as a function that incorporates a measure of linear extent; e.g., a predicate that is true of degrees corresponding to something like 'the degree of length that an average child grows in a month'.

The second condition will handle the contrast between (24a) and (25a). The presupposition imposed by the unit nominal *inch* is that its degree argument be a positive degree of linear extent, but the negative adjective *low* returns a negative degree.

(24) a. The plant is 17 inches high.
b. $[\![\text{17 inches}]\!](\mathbf{high}(p))$

(25) a. ??The plant is 17 inches low.
b. $[\![\text{17 inches}]\!](\mathbf{low}(p))$

(26) $[\![\text{inch}]\!] = \lambda d : d \in Dom(\textbf{l-extent}).d = \textbf{l-extent}(i)$

What about cases like (27)? Maybe some positive adjectives do not actually encode the same measure function as that encoded by the appropriate unit measure?

(27) ??This rock is 30 ounces heavy/light.

(28) $[\![\text{ounce}]\!] = \lambda d : d \in Dom(\mathbf{weight}).d = \mathbf{weight}(oz)$

This can't be quite right, because of comparatives like those in (29):

(29) a. This rock is 30 ounces heavier/lighter than that one.
b. This rock has a weight of 30 ounces.

We might be able to handle this in terms of scale structure: maybe the only difference between the domain of **heavy** and **weight** is that the former doesn't include the zero point of the scale, while the latter does? Actually, I'm not sure this works. There is a puzzle here that needs solving....

3.2 Degree predicates or degree quantifiers?

In support of the claim that MPs are predicates of scalar intervals, Schwarzschild observes that the quantifier in a MP must be weak.

(30) *most feet taller, *most feet of yarn, *ran most miles, *most inches above the painting, *weigh most ounces

(31) a. I regretted every mile farther that I had to walk.
b. A center makes use of every inch that he is taller than his opponent.
c. Max weighed every ounce that he expected to weigh after Thanksgiving dinner.

Would this lead us to expect that MPs should always remain inside the scope of other quantificational expressions? This is a property of other expressions that are often analyzed as predicative, like bare plurals and mass nouns.

(32) a. We might see dogs in the park.
b. Everyone ate pasta.

Heim (2000) argues that the ambiguity of the following sort of example demonstrates that comparatives (qua degree quantifiers) can take scope over at least some other quantificational expressions, contrary to what is claimed in Kennedy 1999.

CONTEXT: Student turns in a 10 page paper. The professor says:

(33) Your paper is required to be exactly 6 pages longer than that.
a. $\forall w \in Acc : 6pp(max\{d \mid \text{the paper is } d\text{-long}\} - 10\text{pp})$ *at most 16pp.*
b. $6pp(max\{d \mid \forall w \in Acc : \text{the paper is } d\text{-long}\} - 10\text{pp})$ *at least 16pp.*

It is possible to account for this ambiguity without scoping out the comparative, however, if we allow MPs to scope out.

(34) $[\![\text{exactly MP}]\!] = \lambda D_{\langle d,t \rangle}.max(D) = \text{MP-much}$

(35) a. $\forall w \in Acc : max\{d \mid \textbf{long}(\text{the paper}) \succeq 10\text{pp} + d\} = 6\text{pp}$ *at most 16pp.*
b. $max\{d \mid \forall w \in Acc : \textbf{long}(\text{the paper}) \succeq 10\text{pp} + d\} = 6\text{pp}$ *at least 16pp.*

We seem to need to allow for this sort of scoping for MPs, considering the fact that (36) is ambiguous in the same way as the comparatives:

(36) Your paper is required to be exactly 16 pages long.
a. $\forall w \in Acc : max\{d \mid \textbf{long}(\text{the paper}) \succeq d\} = 16\text{pp}$ *at most 16pp.*
b. $max\{d \mid \forall w \in Acc : \textbf{long}(\text{the paper}) \succeq d\} = 16\text{pp}$ *at least 16pp.*

This suggests that we may need to rethink Schwarzschild's proposal in terms of a quantificational analysis of MPs.

Setting this aside, though, one thing we can conclude is that whenever we have a MP, we also have a measure function somewhere in the representation to provide the degree that the MP holds of (or is related to).

4 Measurement inside the nominal projection

4.1 (Pseudo-)partitives and compounds

The constructions under consideration:

(37) a. MP of $[_{\text{NP}}$ *head* $]$ — *Pseudo-partitive*
b. (Det) MP $[_{\text{Nproj}}$ *head* $]$ — *Compound*
c. MP of $[_{\text{DP+def}}$ *head* $]$ — *Partitive*

Schwarzschild claims that MPs are subject to different semantic licensing conditions when they appear in pseudopartitives and compounds. Specifically:

(38) a. MPs in (pseudo-)partitives are acceptable only if they measure a property that is *monotonic* with respect to the head.
b. MPs in compounds are acceptable only if they measure a property that is *non-monotonic* with respect to the head.

(39) *Monotonicity*
A property is monotonic if it tracks part-whole relations.

The following contrasts illustrate these constraints in action. Mass nouns (by virtue of their meanings) come with a part-whole relation: the *material part* relation discussed in Link 1983. This means that MPs that measure degrees that are monotonic with respect to this relation are OK in pseudopartitives; those that are bad in compounds.

(40) VOLUME is monotonic wrt *dirt*
a. I need 2 ft^3 of dirt.
b. ??I need (some) 2 ft^3 dirt.

(41) TEMPERATURE is non-monotonic wrt *water*
a. ??I need 30 degrees of water.
b. I need (some) 30 degree water.

Plurals, like mass nouns, come with a part-whole structure (Link's *individual part* relation). Pseudopartitives w/MPs that are montonic wrt this relation are OK, and the same MPs in compounds are necessarily interpreted below plural morphology.

(42) WEIGHT is monotonic wrt *marbles*
a. two kilos of marbles
b. (some) two kilo marbles

(43) VELOCITY is non-monotonic wrt *particles*

a. ??10,000 kph of particles

b. (some) 10,000 kph particles

Non-monotonicity may obtain either because the property is non-monotonic for the noun, as in (41), or because the noun denotation doesn't come with a part-whole relation, as in the case of count nouns, which are properties of atoms. Thus we only get MP compounds in examples like (44)-(45).

(44) LENGTH is non-monotonic wrt *shovel*

a. ??I need six feet of shovel.

b. I need a six foot shovel.

(45) WEIGHT is non-monotonic wrt *baby*

a. ??She gave birth to 3 kilos of baby.

b. She gave birth to a 3 kilo baby

The prediction is that we should never get MPs in count noun pseudopartitives. But what about 'true' partitives?

(46) a. 17 inches of ??(the) shovel

b. 2 hours of ??(the) job

According to RS, these are OK because the *of* here, unlike the *of* in pseudo-partitives, has semantic content: it takes an entity and returns back a property true of parts of the entity. In other words, the part-whole relation doesn't come from the count noun (as we saw above), rather it comes from the meaning of the partitive construction.

(47) $[\![of_{prt}]\!] = \lambda x \lambda y.y$ is a part of x

The difference between partitives and pseudopartitives, then, is that in the former, NP is enough to give monotonicity, while in the latter it is the *of DP* constituent that is relevant. Otherwise, things are exactly the same.

4.2 Schwarzschild's analysis

RS argues that these semantic constraints are connected to syntactic differences between MPs in partitives and MPs in compounds:

- The former fall in some specifier of the extended nominal projection.
- The latter are in the same position as attributive adjectives.

Both of these claims are probably true: in a number of languages, expressions corresponding to the English compounds are clearly adjectival. He also claims that attributives in general are non-monontonic, though I didn't quite follow this argumentation. We'll come back to these points shortly.

So the relevant constraints are:

(48) a. A MP in a specifier in the extended nominal projection must be monon551onic.
b. Attributives must be non-monotonic.

But if MPs can occur in both places, how do we get the difference in monotonicity? Do they have different meanings in the two types of constructions? Sort of.

Recall that MPs are predicates of degrees, so we need to get a measure function into the picture somewhere — this is the expression that 1) gives us the degree that the MP is predicated of, and 2) introduces the property that has to be monotonic wrt the denotation of the head.

(49) a. 2 ft^3 of dirt
b. $\lambda x.dirt(x) \wedge [\![2 \text{ feet}^3]\!](\mathbf{volume}(x))$

(50) a. 35 degree water
b. $\lambda x.water(x) \wedge [\![35 \text{ degree}]\!](\mathbf{temperature}(x))$

But where does the measure function come from? (Also, should we be worried about the morphology in (50)???) Three possible answers:

1. it comes from the MP,
2. it comes from a morpheme distinct from both the MP and the nominal, or
3. it comes from the nominal.

RS goes with a version of the first answer, whereby a MP in one of these constructions is augmented with a measure function when it is interpreted, so that the individual object that the head of the construction is predicated of is mapped to an appropriate scale (in the appropriate way).

This augmentation is context-dependent: in Spec/partitive position, a MP is augmented according to (51a), and in attributive position, it is augmented according to (51b).

(51) a. MON: MP $\rightarrow \lambda P \lambda x.P(x) \wedge [\![\text{MP}]\!](\mu(x))$
CONDITION: μ is monotonic on P
b. NONMON: MP $\rightarrow \lambda P \lambda x.P(x) \wedge [\![\text{MP}]\!](\mu(x))$
CONDITION: μ is not monotonic on P

(52) a. 2 inches of snow
b. 2 cm rope

So at the end of the day, the interpretation of MPs in partitives and compounds is exactly the same, except for the conditions (presuppositions?) imposed on the measure functions they incorporate in the two cases.

4.3 Some questions

1. Do we really want to put a measure function inside the meaning of a MP? Or is RS assuming that we only put it there if we need it? In other uses of MPs, like the ones we were discussing above with gradable ajectives, we *don't need it* because it's already provided by another expression (the adjective):

(53) a. Julian is 15 months old.
b. $[\![15 \text{ months}]\!](\mathbf{old}(j)))$

(54) a. Julian is 18 months younger than Nicholas.
b. $[\![18 \text{ months}]\!](\mathbf{young}(j) - \mathbf{young}(n))$

2. Does the story so far tell us *why* the (non-)monotonicity constraints hold? I don't think so. Presumably this should follow from some difference in the meaning or structure of the two types of constructions.

3. Do we get monotonicity effects when MPs combine with categories other than N(P)?

5 An alternative picture

5.1 Two new bits of data

1. Examples like those in (55) show that we can iterate MPs. (Maybe: these are 'classifier' constructions.)

(55) a. many truckloads of baskets of heads of cabbage
b. several boxes of reams of sheets of paper

The 'counter' always comes at the top:

(56) a. many truckloads of (*many/three/several) baskets of (*many/three/several) heads of cabbage
b. several boxes of reams of (*a bit/a lot) of paper

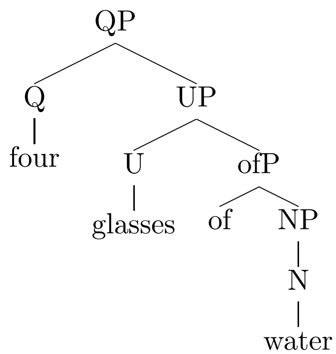
The unit nominals obey/give rise to the monotonicity constraints:

(57) a. many truckloads of 6 bushel baskets of heads of cabbage
b. ??many truckloads of 6 bushels of baskets of heads of cabbage

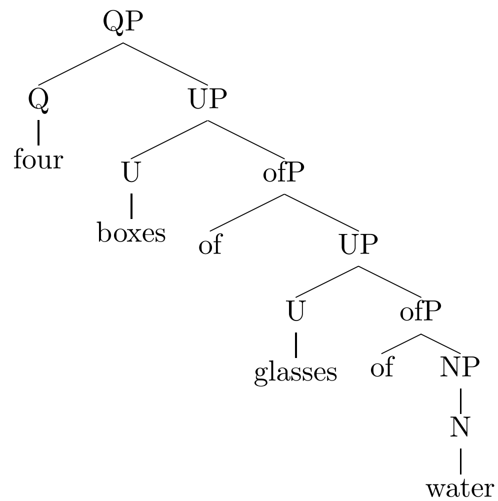
(58) a. four glasses of water
b. ??16 oz. of glasses of water
c. four 16 oz. glasses of water
d. four large glasses of water
e. four ice-cold glasses of water
f. four glasses of ice-cold water

What all this suggests is that the constituent structure we should be considering is something more like (59), where U(nit)P can itself be the argument of another UP.

(59) a.



b.



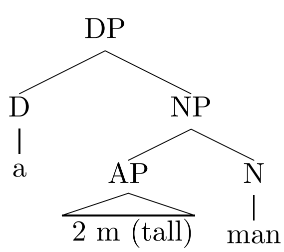
2. When we look at compounds, we see that sometimes the MP can come with an adjective: (60a) and (60b) seem to mean the same thing.

(60) a. a six foot shovel
b. a six foot long shovel

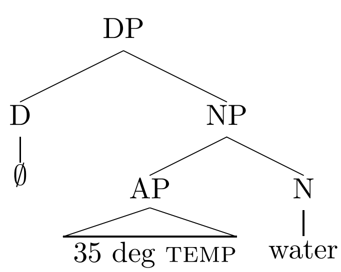
This suggests that MPs in compounds are not adjectives themselves, but rather just the degree arguments of (possibly implicit) adjectival/measure function heads.

(61) a. a 2 meter (tall) man
b. a 3 hour (long) class
c. 35 degree (*temperature) water
d. a 7 lb (*heavy) baby

(62) a.



b.



Do these reconsiderations of the structures involved here shed any light on why the monotonicity constraints hold? If this picture is right, then there is at least one clear difference between the two constructions:

- In 'compounds', the measure function required by the MP is provided by an adjectival element.
- In partitives, it comes from somewhere else. The fact that the distribution of MPs in partititives is sensitive to part-whole relations suggests that it should somehow come from some element of the partitive construction itself!

5.2 Partitives

Is it possible that the *of* in pseudopartitives to be an occurrence of the same *of* we get in partitives: both are looking for arguments that can be subjected to a a PART-OF relation. (Why don't we get pseudo-partitives with count nouns, if this is correct?)

To answer this question, we need to take a closer look at partitives, which is what we're going to do next week. So let's come back to this problem later, and just think about (so-called) compounds today.

5.3 Attributive MPs, aka 'compounds'

The simplest solution I can think of, which is just to analyze the APs in (62) as properties of individuals (i.e., to give them the same analysis they'd have in predicative position), certainly doesn't force monotonicity based on part-whole relations:

(63) a. $[\![[_{AP}\text{ 6 foot tall}]]\!] = \lambda x.[\![\text{6 feet}]\!](\mathbf{tall}(x))$
b. $[\![[_{AP}\text{ 35 degree (TEMP)}]]\!] = \lambda x.[\![\text{35 degree}]\!](\mathbf{temp}(x))$

This doesn't seem to require non-monotonicity either, however. But maybe this is not a bad thing?

(64) a. 60 minutes of analysis
b. a 60 minute (long) analysis

RS's argument that attributives are not monotonic:

(65) a. ??(some) 2 ft^3 dirt
b. $\lambda x.dirt(x) \wedge [\![2\text{ ft}^3]\!](\mathbf{volume}(x))$

(66) a. ??(some) 2 liter water
b. $\lambda x.water(x) \wedge [\![2\text{ liter}]\!](\mathbf{volume}(x))$

So we're back at the drawing board. Maybe Roger will enlighten us when he comes to give his presentation....

5.4 More data to think about

There is a third form to consider: *NP of MP* constructions.

(67) a. 2 liters of oil
b. ??2 liter oil
c. ??oil of 2 liters

(68) a. ??100 degrees of oil
b. 100 degree oil
c. oil of 100 degrees — cf. Spanish, Dutch
d. *exactly 100 degree oil
e. oil of exactly 100 degrees

And what about cases in which the nominal names a scale?!?

(69) a. 6 feet of height
b. a 6 foot height
c. a height of 6 feet

(70) a. I placed the mirror at *(69a)/(69b)/(69c).
b. John has (69a)/*(69b)/(69c)

(71) a. 6 degrees of separation
b. a 6 degree separation
c. a separation of 6 degrees

Finally, are 'inverted' degree constructions or 'N of an N' constructions at all relevant?

(72) a. I took too big (of) a piece of pie
b. Max wrote so long (of) an introduction to his book that the editor had to shorten it.
c. How small (of) a car did you buy?

(73) a. For if you see Tom O'Neill as he is, not as conformity forces us to see, then there is coming into the room a lovely spring rain of a man. *NYTimes Book Review*, 3/11/01
b. This was a three ring circus of a game. *NY Times*, 4/15/02

5.5 Where are we?

I'm not sure, but I'm hoping that after we take a closer look at partitives and classifier constructions in the next few weeks, and after we hear Roger talk on October 17, we'll have a better idea of what's going on here.

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