On Amounts and Measures

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14th Tbilisi Symposium on Logic, Language and Computation
September 22, 2023

Leibniz-Zentrum
Allgemeine Sprachwissenschaft

Degree constructions in natural language

(1) Bart is 20 cm taller than Lisa.   adjectival

(2) The suitcase weighs 20 kilograms.   verbal

(3) a. Mabel bought 40 sheep.   quantity
     b. The aquarium holds 10 gallons of water.

$\rightarrow$ Require something like degrees as part of the ontology.

What are degrees?

- Numbers (Krifka, 1989)
- Points on a scale (Heim, 2000; Kennedy, 2007)
- Scalar intervals (Kennedy, 2001; Schwarzschild and Wilkinson, 2002)
- Equivalence classes (Cresswell, 1977; Bale, 2008)
- Kinds (Anderson and Morzycki, 2015; Scontras, 2017)

Points of debate

What is measured?

- Individuals (Heim, 2000; Kennedy, 2007, etc.)
- Extents or vectors (Zwarts and Winter, 2000; Faller, 2000; Schwarzschild, 2012)
- States (Wellwood, 2019)
- Tropes (Moltmann, 2009)

$\rightarrow$ Some of these require us to posit additional sorts of entities beyond individuals (type e) and degrees (type d).

Type 1: Numerical NP + *much/many* nominal

(4)   a.   Ten kilos of chicken is **too much food**.   (a) substance nominal

         b.   Ten kilos of chicken is **too much weight**.   (b) property nominal

         c.   Ten kilos of chicken is **too much work**.   (c) eventive nominal

Type 1: Numerical NP + *much/many* nominal

(5) a. Five dogs is **too many pets**.   (a) substance nominal

   b. Five dogs is **too much weight**.   (b) property nominal

   c. Five dogs is **too much work**.   (c) eventive nominal

Amount and measure predication

Type 2: Measure expression + gradable adjective

(6) a. 20 kilograms is **too heavy** (for a suitcase you have to carry).
          cf. The suitcase is too heavy.

     b. $500 is **too expensive** (for a coat).
          cf. The coat is too expensive.

     c. Six feet (tall) is **too tall**.
          cf. Fred is too tall.

(Solt, 2008)

Type 3: Property nominal + gradable adjective

(7)

    a. I was worried about the **heavy weight** of the suitcase.

    b. Fred's **tall height** made him a natural for the basketball team.

    c. Mabel is wise despite her **young age**.

    d. Although the **size** of the stains was **small**, they were so obvious that I couldn't wear the shirt.

(Solt, 2008)

What can amount and measure predication tell us about the semantics of degree in natural language?

Roadmap

1. Amount predication – type 1a

2. *Weight*, *height*, *size*, . . .

3. Back to amount predication

4. Conclusions

Amount predicates – type 1a

(8) a. Ten kilos of chicken is **too much food**.

 b. Five dogs is **too many pets**.

- Joint work with Jon Ander Mendia (see also Mendia & Espinal ms.).

Properties

Singular form of copula:

(9) a. Ten kilos of chicken is/are rotten.

   b. Ten kilos of chicken is/??are too much food.

(10) a. Five dogs *is/are barking.

   b. Five dogs is/??are too many pets.

Properties

Lack of existential commitment:

(11) a. Ten kilos of chicken are rotten.
         → some particular 10-kg portion of chicken

      b. Ten kilos of chicken is too much food.
         → 10 kg of chicken as an **amount** of food

(12) a. Five dogs are barking.
         → some particular 5 dogs

      b. Five dogs is too many pets.
         → 5 dogs as a **number** of pets

Properties

Lack of existential commitment:

(13) a. Ten kilos of chicken are rotten.
          $\rightarrow$ some particular 10-kg portion of chicken

      b. Ten kilos of chicken is too much food.
          $\rightarrow$ 10 kg of chicken as an **amount** of food

(14) a. Five dogs are barking.
          $\rightarrow$ some particular 5 dogs

      b. Five dogs is too many pets.
          $\rightarrow$ 5 dogs as a **number** of pets

Properties

ZAS

Required presence of *much/many*:

(15) a. Ten kilos of chicken is **too much food**.

b. . . . is **more food** than we need.

c. . . . is **less food** than we paid for.

d. . . . is **as much food** as we ordered last year.

e. . . . is **so much food** that we'll have leftovers.

f. . . . isn't **much food**.

g. . . . ??is **food**. (cf. Chicken is food.)

Properties

Z A S

Required presence of *much/many*:

(16) a. Five dogs is **too many pets**.

   b. . . . is **more pets** than I could handle!

   c. . . . is **fewer pets** than my cousin has.

   d. . . . is **as many pets** as we can keep in the apartment.

   e. . . . is **so many pets** that the vet bills will make us go broke.

   f. . . . isn't **many pets**.

   g. . . . *is **pets**.

Properties

Presuppositional behavior:

(17)   Ten kilos of broccoli / #rocks is (not) too much food.

(18)   Five cats / #rocks is (not) too many pets.

- Entities in extension of subject nominal presupposed to be in extension of predicate nominal.

Core idea

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Type 1a amount predicates are (like they seem on the surface) predicative in their semantics – predicating a property of an amount or quantity:

- 10 kg of chicken as an amount of chicken

- 5 dogs as a quantity of dogs

But what are amounts / quantities?

$\rightarrow$ Not simply numbers or points on a scale!

Amounts/degrees and kinds

Parallels between degrees and kinds:

(19)   <u>Polish</u> (Anderson and Morzycki, 2015):

    a.   **taki**   *pies*
            such-MASC dog

         'such a dog', 'a dog of that kind'

    b.   **tak** *wysoki*
            such tall

         'that tall' (degree)

Amounts/degrees and kinds

Scontras (2017): Amounts/degrees, like kinds, can be understood as nominalizations of properties, via 'down' operator $^\cap$ (Chierchia, 1998):

(20) $[\![\text{dog}_{kind}]\!] = {}^\cap\lambda x.dogs(x)$ a sort of entity

(21) $[\![\text{three kilos of apples}_{amount}]\!] = {}^\cap\lambda x.\mu_{kg}(x) = 3 \land apples(x)$

$\rightarrow$ Nominalization of a **quantity-uniform** property.

(see also Rothstein 2017; Anderson and Morzycki 2015)

Amounts/degrees and kinds

However:

- Nominalization operator $\cap$ originally applied to predicates with **cumulative** reference.

  (22) CUM(P) iff $\forall x, y \in P, x \sqcup y \in P$

    - Kind associated with maximal plurality in a world.

- Predicates such as *three kilos of apples* have **quantized** reference:

  (23) QUA(P) iff $\forall x, y, x \in P \land y \in P \rightarrow \neg x \sqsubset y$

Amount formation

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Amount-formation and amount-realization operators:

⋒   maps quantized (quantity-uniform) predicate to amount (type a)

⋓   maps amount to set of entities realizing that amount (type $\langle a, t \rangle$)

$\rightarrow$ Here we assume amounts are a variety of individual, i.e. $D_a \subset D_e$

Amount formation

Predicative interpretation:

(24) $[\![10 \text{ kilos of chicken}_{\langle e,t \rangle}]\!] = \lambda x.chicken(x) \wedge \mu_{kg}(x) = 10$

Amount formation:

(25) $[\![10 \text{ kilos of chicken}_a]\!] = {}^{\cap}\lambda x.chicken(x) \wedge \mu_{kg}(x) = 10$

- The entity (amount) correlate of the property of being a 10-kg portion of chicken

On amounts

- Based on a more basic notion of degree

  (26) $[\![10 \text{ kilos of chicken}_a]\!] = {}^{\cap}\lambda x.chicken(x) \land \mu_{kg}(x) = 10$

- More complex than simple degrees
    - *10 kilos of chicken* vs. *10 kilos of rocks*

- Underlying measurement scale can provide basis of ordering...
    - *10 kilos of chicken is more food than 5 kilos of chicken.*

- ...but need not
      10 kilos of chicken is more food than 5 bags of chips.

Compositional analysis

(26)   Ten kilos of chicken is too much food.

ten kilos of chicken   too much food
amount   predicate of amounts

Role of *much*

Creates predicates of amounts:

(26) $[\![too\ much]\!]= \lambda P_{\langle e,t\rangle}\lambda a_a : \exists X \subseteq P[\mathsf{QUA}(X)\wedge a = {}^{\mathbb{m}}X].\ a \succ_{DIM} \theta_P$

(27) $[\![too\ much\ food]\!]=$
        $=\lambda a_a : \exists X \subseteq [\![food]\!][\mathsf{QUA}(X) \wedge a = {}^{\mathbb{m}}X].\ a \succ_{DIM} \theta_{food}$

- predicate of amounts
- presupposed to be amounts of food
- asserted to be greater wrt. dimension DIM than threshold θ_{food}

Role of *much*

Creates predicates of amounts:

(28) $\llbracket too\ much \rrbracket = \lambda P_{\langle e,t \rangle} \lambda a_a : \exists X \subseteq P[\mathsf{QUA}(X) \wedge a = {}^{\mathbb{m}}X].\ a \succ_{DIM} \theta_P$

(29) $\llbracket too\ much\ food \rrbracket =$
$= \lambda a_a : \exists X \subseteq \llbracket food \rrbracket [\mathsf{QUA}(X) \wedge a = {}^{\mathbb{m}}X].\ a \succ_{DIM} \theta_{food}$

- predicate of amounts
- presupposed to be amounts of food
- asserted to be greater wrt. dimension DIM than threshold θ_{food}

Compositional analysis – putting it together

(30) a. Ten kilos of chicken is too much food.

  b. $^{\cap}\lambda x.chicken(x) \wedge \mu_{kg}(x) = 10 \succ_{DIM} \theta_{food}$,

  where it is presupposed that $^{\cap}\lambda x.chicken(x) \wedge \mu_{kg}(x) = 10$ is an amount of food.

An issue

(31) We bought too much food.

$$\begin{array}{cc}
\text{we bought} & \text{too much food} \\
\lambda x_e.bought(we, x) & \lambda a_a.a \succ_{DIM} \theta_{food} \\
\text{predicate of individuals} & \text{predicate of amounts}
\end{array}$$

$\rightarrow$ type clash!

Amount-to-individual shift

(32) $[\![SHIFT]\!] = \lambda A_{\langle a,t \rangle} \lambda x_e.\exists a \in A[x \in {}^{\cup}a]$

- Shifts predicate of amounts to predicate of individuals realizing those amounts

(33)   a.   We bought SHIFT(too much food).

   b. $\exists x \exists a[\text{too-much-food}(a) \wedge x \in {}^{\cup}a \wedge \text{bought}(we, x)]$

Amount-to-individual shift

(34) $[\![SHIFT]\!] = \lambda A_{\langle a,t \rangle} \lambda x_e . \exists a \in A[x \in {}^{\cup}a]$

- Shifts predicate of amounts to predicate of individuals realizing those amounts

(35)   a.   We bought SHIFT(too much food).

        b. $\exists x \exists a[\text{too-much-food}(a) \wedge x \in {}^{\cup}a \wedge \text{bought}(we, x)]$

Extending the account

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(36) a. Ten pounds of chicken is too much **weight**.   type 1b

     b. Five dogs is too much **weight**.

(37) a. Ten pounds of chicken is too much **work**.   type 1c

     b. Five dogs is too much **work**.

Amount predication - type 1c

Event type can be made explicit:

(38)   a.   Five dogs is too much work.

        b.   Grooming five dogs is too much work.

        c.   Walking five dogs . . .

        d.   Taking care of five dogs . . .

        e.   etc.

Amount predication - type 1c

Explicit event nominal: ⋒ applied to set of events

(39)   a.   Grooming five dogs . . .

       b. $^{⋒}\lambda e.\text{grooming}(e) \wedge \exists x[\text{five-dogs}(x) \wedge PATIENT(e, x)]$

No explicit event nominal: contextually supplied event type E

(40)   a.   Five dogs . . .

       b. $^{⋒}\lambda e.E(e) \wedge \exists x[\text{five-dogs}(x) \wedge THEME(e, x)]$

Amount predication - type 1c

Explicit event nominal: ⋒ applied to set of events

(41) a. Grooming five dogs . . .

  b. $^{⋒}\lambda e.\text{grooming}(e) \wedge \exists x[\text{five-dogs}(x) \wedge PATIENT(e, x)]$

No explicit event nominal: contextually supplied event type E

(42) a. Five dogs . . .

  b. $^{⋒}\lambda e.E(e) \wedge \exists x[\text{five-dogs}(x) \wedge THEME(e, x)]$

Amount predication - type 1b

(43) **Ten kilos of chicken** is too much food.

- Entity correlate of set of 10-kg portions of chicken

(44) **Ten kilos of chicken** is too much weight.

- Entity correlate of set of 10-kg portions of weight??

Property nominals

(45) a. weight   measurable dimension
      b. height
      c. size
      d. depth
      e. length
      f. etc.

(46) a. beauty   non-measurable property
      b. wisdom
      c. etc.

Observation

Property ascription via possessive + property nominal:

(47) <u>German</u>:
      Ich habe Hunger.
      I   have hunger

      'I am hungry.'

(48) <u>Spanish</u>:
      Kim tiene sueño.
      Kim has   tiredness

      'Kim is tired.'

(Francez and Koontz-Garboden, 2015)

Observations

Property ascription via possessive + property nominal:

(49) <u>Hausa</u>:
Munà   dà   ƙarfī̃r.
We-CONT with strength

'We are strong.'

(Francez and Koontz-Garboden, 2015)

Property nominals as mass nouns

Compatibility with *much*:

(50) a. With **so much height**, I found wherever I lay, I still felt the support of the double layered cushioning inside...

   (www.telegraph.co.uk/recommended/home/best-pillows-luxurious-nights-sleep/)

   b. **How much depth** is required to load a boat onto the dock?

   (www.wavearmor.com/blog/faqs)

   c. Correct stall width ... helps horses to balance. ... **Too much width** can get them in trouble.

   (equispirit.com/info/trailer-talk/trailer-size.htm)

- See Francez and Koontz-Garboden (2017)for discussion of the cross-linguistic picture.

Property nominals as mass nouns

Divergence from ordinary mass nouns – fixed dimension:

(51) How much water?

- volume
- weight
- depth
- etc.

(52) How much height?

- height

Property nominals as mass nouns

Divergence from ordinary mass nouns – dependent:

(53)   a.   The height **of the girl**

       b.   The size **of the stain**

       c.   The weight **of the suitcase**

            (cf. The hole **in the bucket**)

Semantics of property nominals

Property nominals denote **substances**, specifically **sets of portions** of abstract substances **associated with** individuals (Francez and Koontz-Garboden, 2015, 2017).

- Substances are a sort of individual, i.e. $D_m \subset D_e$

Semantics of property nominals

For a property nominal α associated with property $prop$:

(54) $\llbracket \alpha_{\langle m,t \rangle} \rrbracket = \lambda m.prop(m)$

(55) $\llbracket \alpha \rrbracket$ is a join semilattice without bottom element, ordered by:

    a.   the inclusion relation $\sqsubseteq$

    b.   the ordering relation $\succeq$
- transitive
- reflexive
- but not antisymmetric

Semantics of property nominals

For example:

(56) $\llbracket \text{height}_{\langle m,t \rangle} \rrbracket = \lambda m.height(m)$

- The set of 'portions' of height
- Mereologically structured via $\sqsubseteq$
- Ordered by height via $\succeq$
- Two distinct portions of height may be equivalent under $\succeq$

Substances and individuals

Abstract substances are related to the individuals that bear them via the relation B:

(57) $[\![$Anna's height$]\!] = max(\lambda m.height(m) \wedge B(anna, m))$

Related notions:

- **Tropes** (Moltmann, 2009): particular instantiations of properties in individuals
- **States** (Wellwood, 2019): entities that individuals can participate in or instatiate; non-dynamic counterparts of events and processes

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Back to amount predication

ZAS

Having established a semantics for property nominals, we are in the position to extend the account of amount predication.

Amount predicates - type 3

(59)   a.   the girl's **tall height**

       b.   the **tall girl**

(60)   a.   the **heavy weight** of the suitcase

       b.   the **heavy suitcase**

(61)   a.   The **size** of the stains was **small**.

       b.   The **stains** were **small**.

Individual–substance correspondences

We must posit that dimensional adjectives exhibit systematic polysemy:

(62) $[\![\text{tall}_{\langle e,t\rangle}]\!] = \lambda x.\mu_{HEIGHT}(x) > d_{Std}$ \hfill individual

(63) $[\![\text{tall}_{\langle m,t\rangle}]\!] = \lambda m : height(m).\mu(m) > d_{Std}$ \hfill substance

Putting it together – type 3

(64) a. Anna's tall height made her a natural for the basketball team.

   b. $\text{tall}_{\langle m,t \rangle}(\text{Anna's height})$

   c. $\mu(max(\lambda m.height(m) \wedge B(anna, m))) > d_{Std}$

   $\rightarrow$ NB: Full compositional analysis requires account of non-restrictive modification.

Amount predication - type 1b

(64) Ten kilos of chicken is too much food.

- Entity correlate of set of 10-kg portions of chicken

(65) Ten kilos of chicken is too much weight.

- Entity correlate of set of 10-kg portions of weight??

Extending the account

Z A S

Begin with ordinary predicative interpretation:

(66) $[\![10 \text{ kilos of chicken}_{\langle e,t \rangle}]\!] = \lambda x.chicken(x) \wedge \mu_{weight}(x) = 10kg$

Extend $\langle e, t \rangle - \langle m, t \rangle$ correspondence:

(67) $[\![10 \text{ kilos of chicken}_{\langle m,t \rangle}]\!] =$
      $= \lambda m.weight(m) \wedge \mu(m) = 10kg \wedge \exists x[chicken(x) \wedge B(x,m)]$

Shift to amount (entity) correlate:

(68) $[\![10 \text{ kilos of chicken}_a]\!] =$
      $= {}^\cap \lambda m.weight(m) \wedge \mu(m) = 10kg \wedge \exists x[chicken(x) \wedge B(x,m)]$

Extending the account

ZAS

Begin with ordinary predicative interpretation:

(69) $[\![10 \text{ kilos of chicken}_{\langle e,t \rangle}]\!] = \lambda x.chicken(x) \wedge \mu_{weight}(x) = 10kg$

Extend $\langle e, t \rangle - \langle m, t \rangle$ correspondence:

(70) $[\![10 \text{ kilos of chicken}_{\langle m,t \rangle}]\!] =$
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Shift to amount (entity) correlate:

(71) $[\![10 \text{ kilos of chicken}_{a}]\!] =$
$= {}^{\cap}\lambda m.weight(m) \wedge \mu(m) = 10kg \wedge \exists x[chicken(x) \wedge B(x,m)]$

Extending the account

Z A S

Begin with ordinary predicative interpretation:

(72) $\llbracket 10 \text{ kilos of chicken}_{\langle e,t \rangle} \rrbracket = \lambda x.chicken(x) \wedge \mu_{weight}(x) = 10kg$

Extend $\langle e, t \rangle - \langle m, t \rangle$ correspondence:

(73) $\llbracket 10 \text{ kilos of chicken}_{\langle m,t \rangle} \rrbracket =$
$= \lambda m.weight(m) \wedge \mu(m) = 10kg \wedge \exists x[chicken(x) \wedge B(x, m)]$

Shift to amount (entity) correlate:

(74) $\llbracket 10 \text{ kilos of chicken}_a \rrbracket =$
$= {}^{\cap}\lambda m.weight(m) \wedge \mu(m) = 10kg \wedge \exists x[chicken(x) \wedge B(x, m)]$

Putting it together – type 1b

(75)   Ten kilos of chicken is too much weight.

ten kilos of chicken   too much weight
amount of weight   predicate of amounts of weight

A complication

Mass vs. count uses:

(75)   a.   How much height . . .   MASS

       b.   The heights of the girls   COUNT
            (cf. *stone*/*stones* etc.)

- Which of these involved in *Anna's tall height* (type 3)?

See also McNally (2022)

A complication

Non-extensive dimensions:

(76) a. The warm temperature (cf. the warm day)   type 3

     b. The temperatures of the lab samples

     c. #How much temperature . . .   type 1b

$\rightarrow$ Maybe not all properties can be construed as abstract 'stuff'.

Amount predicates - type 2

Can the same analysis be extended to type 2 amount predicates?

(77)   20 kilograms is too heavy.

Note however:

(78)   ??20 kilograms of baggage is too heavy.

- Suggests *20 kilograms* and *20 kilograms of baggage* are sortally distinct.
- Do we require an additional sort of entity?

Amount predicates - type 2

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(79)   20 kilograms is too heavy.

Note however:

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Conclusions

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▷ Amount predication (or at least some of its varieties) can be analyzed as predication.

▷ Doing so requires positing entities beyond (ordinary) individuals and degrees:
  - amounts (entity correlates of quantized properties)
  - abstract dimensional substances

▷ A consequence is systematic polysemy:
  - quantized property ⇔ amount
  - amoumt ⇔ individual
  - abstract substance ⇔ individual

▷ We haven't gotten rid of simple degrees.

▷ There's still a lot of work to do!

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Thank you!

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