Counting in Language

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1 Number in Language

1.1 Grammatical number distinction

Number is a heavily grammaticized cognitive distinction:

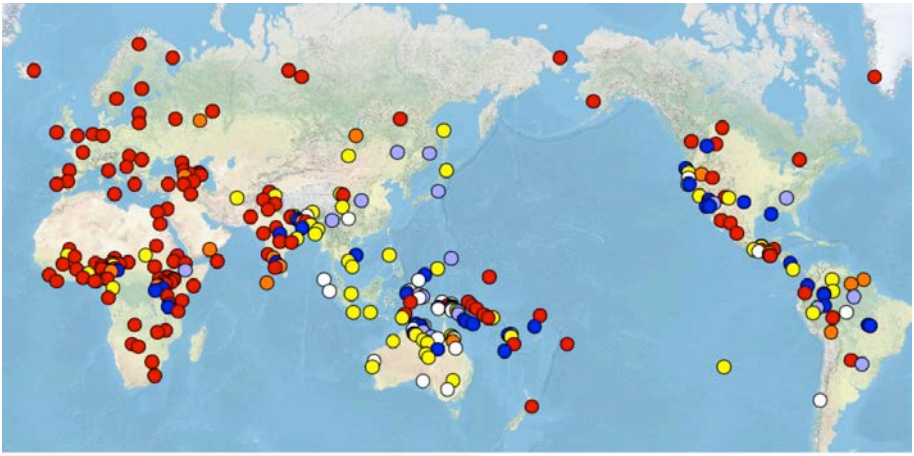
- The vast majority of languages has **number distinctions in personal pronouns** (WALS* 35A: lacking on only 9 of 261 languages, Burmese, American languages)

  e.g. Pirahã:

ti	1st		
gí	2nd	*ti gí*	1st+2nd
hi	3rd	*gí+hi*	2nd+3rd

- A clear majority of languages has **number distinctions in nouns** (WALS 34A: 28 of 291 lg. lack plural; WALS 33A: 98 of 1066 lg. lack plural)
- Far more languages have nominal **number** distinctions than **gender** distinctions (WALS 30A: 145 of 257 languages do not have numeral gender)
- Far more language distinguish nominal number than verbal tense/aspect
- Far more languages distinguish number with nouns than with verbs (verbal number: e.g. semelfactive, iterative).
- But: Number distinctions in nouns are restricted to certain semantic categories.

* World Atlas of Linguistic Structures, http://wals.info



1.2 Beyond singular and plural

- Daakie (Oceanic, Vanuatu)

(1) a. *timaleh kiye Ø-mo koliet* 'The child is singing' singular
b. *timaleh koloo kolo-m koliet* 'The two children are singing' dual
c. *timaleh kiyee kiye-m koliet* 'The few children are singing' paucal
d. *timaleh ngyee la-m koliet* 'The (many) children are singing' plural

- Also reported: trial, quadral (very rare)
- Evidence for bootstrapping effect of dual for number acquisition: Slovenian, Arabic*

Number distinctions can be used for semantic side effects, cognitive extensions:

- Plural for honorofics, e.g. French: *Tu chantes* vs. *Vous chantez.*
- Dual for honorifics in Daakie: *Motlo Abel kolo-m koliet* 'Uncle Abel is singing'
- Paucal for affiliation in Daakie: Reference to large group

(2) *Jisas san vanten kiyee, kiye-m lare ih se Yaapuo van lamwiye*
Jisas his man 3.PC 3.PC-RE lift name of god go up
'The followers of Jesus lifted the name of God so that it went up'

- Plural of abundance, e.g. *the waters of the Nile* (common in Greek, Persian, …)

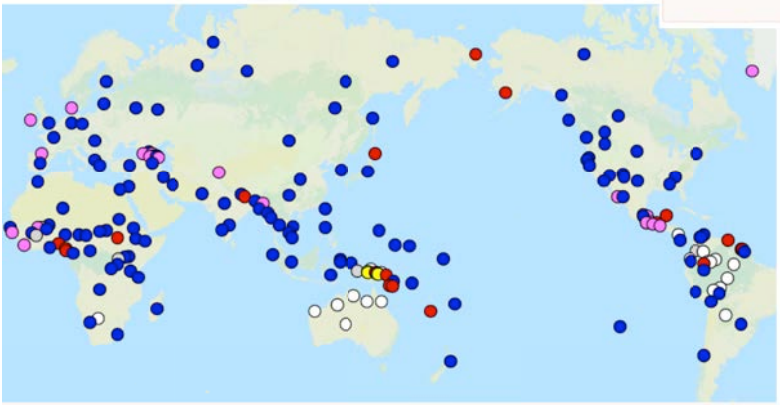
(3) *I baniera ine gemati nero* (sg.) */ nera* (pl.) (Kouneli 2015)
'The bathtub is full with / covered, overflowing with water'

* Almoammer, A et al. 2013. Grammatical morphology as a source of early number word meanings. PNAS 110: 18448-53.

1.3 Numerals

Numerals form a special subsystem within the lexicon

- Lack of number words, e.g. Pirahã
- Restricted number words, e.g. body-part systems in PNG
- Productive recursive number systems with bases of 10, 20, 5, 6, 12 – WALS 131A, B. Comrie



1.4 Recursion and number

In unrestricted numeral systems:

- **Recursivity** of language (Chomsky, Hauser, Fitch 2002)
- meets **infinity** of numbers

Word formation processes in numeral systems:

- Conjunction: *zwei-und-dreißig*
thirty-two
- Subtraction: *duodeviginti* '18' – XVIII
undeviginti '19' – IXX
- Multiplication: *five-hundred*
- Derivation: *seven-teen*
seven-ty
- Suppletion: *eleven, twelve*

Accent patterns and modification:

(4) *PERSONEN-auto* – 'person car', a special car for persons

(5) *ZWEI-und-dreißig* (32) – a special type of 30
ZWEI-hundert (200) – a special type of 100

2 The Mass / Count Distinction

Two classes of common nouns (e.g., Jespersen 1924):

- Mass nouns (ca. 29% in German, 34% in Russian[*]) vs. Count nouns

2.1 Syntactic properties of mass / count nouns

Formation of morphological forms:

(6) Plural forms in English: *apple / apple-s*, but: *gold / *gold-s*

(7) Plural or singulative forms in Welsh (similarly in Dagaare):
afal / afal-au 'apple/s', *ader-yn / adar* 'bird/s' but: *llefrith* 'milk', only one form

Combination with numerals:

(8) With agreeing plural, English: *one apple, *one gold, two apple-s, *two gold(s)*

(9) No agreeing plural, Turkish:
bir elma 'one apple', *iki elma* 'two apples', *elmalar* 'apples'

Combination with certain quantifiers:

(10) *each apple, *each gold,* (*) *much apple, much gold*

Bare singular nouns as full noun phrases:

(11) *There was gold / (*) apples on the table.*

[*] Katarina Gerstenhofer, 2007. Zur Kategorie des Numerus im Vergleich: Massen- und Zählnomina im Deutschen und im Russischen. Magisterarbeit, Humboldt-Universität zu Berlin

Mass / count distinction in classifier languages

- Classifier constructions in Mandarin Chinese;
head nouns select classifier (e.g. *zhi* cats, birds; *tou* domesticated animals)

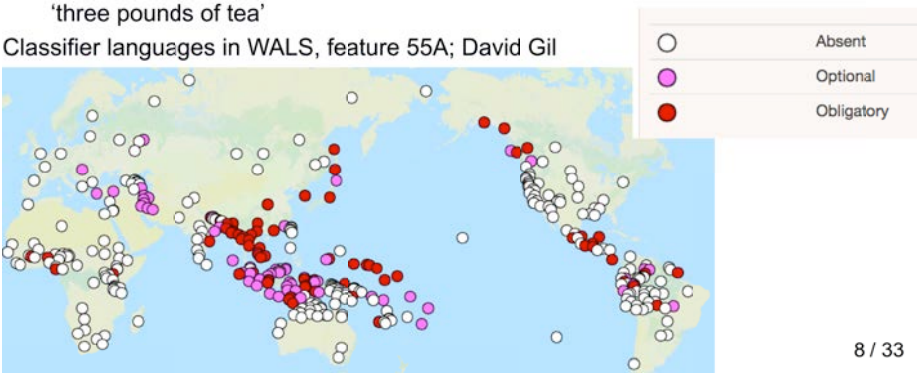
(12)

san ge pingguo	*san zhi mao*	*san tou niu*
three CL apple	three CL cat	three CL cattle
'three apples'	'three cats'	'three heads of cattle'

- Classifier languages are not languages that only have mass nouns;
distinct measure construction, e.g. optional linker *de,* measure word not selected

(13) *san bang (de) cha*
three pound SUB tea
'three pounds of tea'

Classifier languages in WALS, feature 55A; David Gil



2.2 But is mass / count a grammatical distinction?

Mass nouns as count nouns:

- Portion reading: *We ordered three beers.*
- Taxonomic reading: *In Düsseldorf they brew several beers.*

Count nouns as mass nouns:

- Universal grinder: *Put some apple to the salad.*
- Meat of animals: *John doesn't like lamb.*
- Single entities don't count: *There was a lot of sleeping bag in the trunk.* (from Germ.)

Borer 2005:*

- There is no lexical root distinction between mass and count nouns
- Mass / count distinctions depend on syntactic heads that combine with roots

Copestake & Briscoe 1995: derivational rules, alternatively: semantic coercion

Evidence for a basic lexical meaning, cf. Frisson & Frazier 2005**, eye tracking:

- Small penalty for portion reading
- Large penalty for grinder reading

Lexical mass/count distinction allows for ambiguous nouns, e.g. *cake.*

* Borer, Hagit. 2005. *Structuring sense.* Oxford: Oxford UP.
** Frisson, Steven & Lyn Frazier. 2005. Carving up word meaning: Portioning and grinding. *Journal of Memory and Language* 53: 277-291.

2.3 Beyond syntactic singular/plural, mass/count

- Generic / Unit: Bayso (Cushitic, Ethiopia; Corbett & Hayward 1987)

(14) Generic/Unit: *lubán* 'lion' Singulative: *lubán-titi* 'a lion'
Paucal: *lubán-jaa* 'a few lions'
Pural: *luban-jool* 'lions'

- Collective / Singulative: Welsh (Celtic, Great Britain)

(15) Singular: *afal* 'apple' Plural: *afal-au*
Collective: *adar* 'birds' Singulative: *adar-yn* 'a bird'
brics 'bricks' *brick-sen* 'a brick'

- Portion / Distributive (spatially scattered): Daagare (Gur, Ghana; Grimm 2012)

(16) Singular: *bíé* 'a child' Plural *bíí-ri* 'children' Distributive *bie-ɛɛ*
Collective: *bíè* 'seeds' Singulative: *bí-rì* 'a seed' Distributive *bí-ɛɛ*
Sing.mass: *muɔ* 'grass' Portion: *muɔ-ruu* 'blade of grass' Distributive *muɔ-ɛɛ*
Sing.mass *kùó* 'water' Distributive *kùó-ɛɛ*

- Classifier / measure term in classifier languages, already mentioned
- No distinction: Yudja (Tupi, Brazil; Lima 2012), Nez Perce (Penutian, USA; Deal 2013):

(17) *a. k'uyc heecu*
nine wood
'nine pieces of wood'

b. yi-yos-yi-yos mayx
PL-blue sand
'quantities of blue sand' (lit.: 'blue sands')

2.4 Semantic properties of mass / count nouns

Arbitrariness of the mass / count distinction?

cat(s)

*furniture(*s)*

*milk(*s)*

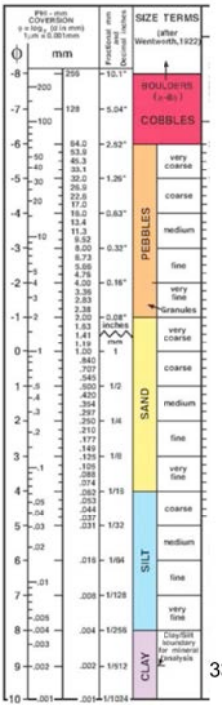
cloud(s)

*police(*s)*

Grains and the role of grain size

*bean(s), pea(s), rice(*s), oat*(s)*

Wentworth scale of grain sizes



2.5 Differences between and within languages

Differences between languages:

(18) Engl. *furniture*, German *Möbel*

Differences within a language:

gold/nuggets

change/coins

drapery/curtains

tiling/tiles

mail / letters

2.6 Hidden mass / count distinctions*

Who has more cats?

Who has more milk?

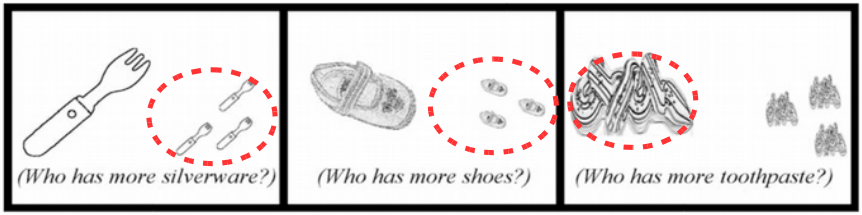
And who has more furniture?

* Visuals: George Scontras

Barner & Snedeker 2005:

- “Object mass nouns” like *silverware, luggage, furniture, jewelry, mail* involve reference to inherently individuable and countable entities
- as opposed to “substance mass nouns” like *mud, space, water*

Linguistic evidence: Quantity judgements



The intermediate status of object mass nouns:

- syntactically, they are mass nouns
- as for comparison with *more* (no mass/count distinction), they work like count nouns, the distinction *fewer* (count) *less* (mass) is obsolete – *less* as unmarked operator

3 Formal Theories of Mass / Count distinction

3.1 Mereological theories

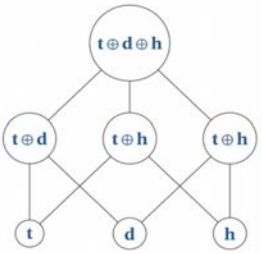
Cf. F.J. Pelletier, G. Link 1983, Chierchia 1998*

Centered around a part relation, $\sqsubseteq$

- reflexive, transitive, antisymmetric
- additional property: unique relative complement
- defines overlap relation, sum operation

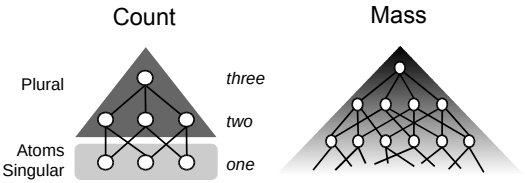
Example:

- The small circles here stand for the children Tom, Dick, and Harry, **atomic** individuals, individuals that have no proper parts.
- The large circles are sums: formal objects that represent pluralities of children.
- The binary sum operation, $\oplus$ or $\sqcup$, is associative, commutative, and idempotent.
- The lines indicate the parthood relation $\sqsubseteq$, a partial order



* Cf. Champollion, Lucas & Manfred Krifka. 2016. Mereology. In: Aloni, Maria, (ed), *The Cambridge Handbook of Formal Semantics*. Cambridge: Cambridge University Press, 513-541.

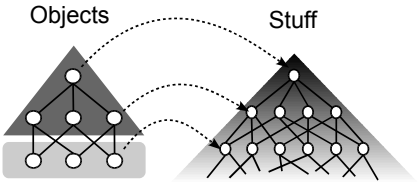
3.2 Mass / Count and atoms



Essential assumptions
(Link 1983, Chierchia 1998)

- Count nouns: mereology with atoms,
- Mass nouns: atomless mereology
- Numerals count atoms,
- Plurals: individuals with ≥2 atoms

Objects and Stuff



- Domain of objects is atomic
- Domain of stuff is atomless
- Concrete objects are mapped to the stuff they consist of (cf. Link 1983)
- Objects may change the stuff they consist of (e.g. living beings, ship of Theseus)

Notion of atom is predicate specific, situation specific:

(19) *army, legion, cohort*
We drank seven beers.

No reference to physical atoms / molecules:

- **There are 40* x 10^{21} *waters in the glass*.

3.3 Atoms in the real world

Mass / count and the real world:

- Count nouns: atoms
- Mass nouns:
  atoms too small, too irrelevant,
  no atomic world view in natural language ontology


apples


rice

Refinement (Landman 2011[*]):

- Count nouns: discrete, non-overlapping atoms
- Mass nouns: If atomic, then vague, overlapping atoms
  "mess nouns" vs. "neat nouns"


ratatouille


water

[*] Landman, Fred. 2011. Count Nouns - Mass Nouns - Neat Nouns - Mess Nouns. *The Baltic International Yearbook of Cognition, Logic and Communication* 6: 1-67.

4 Counting and Measuring in Syntax*

4.1 Measure construction

Measure term applies to nominal predicates

(20) ⟦*three pounds of butter*⟧ = ⟦*three pounds*⟧(⟦*butter*⟧)
= λPλx[pound(x) = 3 ∧ P(x)](λx[butter(x)])
= λx[pound(x) = 3 ∧ butter(x)]

4.2 Classifier construction

Classifier creates a nominal-specific counting unit

(21) ⟦*fifty head of cattle*⟧ = ⟦*fifty head*⟧(⟦*cattle*⟧)
= λP:animal(P) λx[NU(P)(x) = 50 ∧ P(x)](λx[cattle(x)])
= λx[NU(cattle)(x) = 50 ∧ cattle(x)]

where NU: Natural Unit, :animal(P): presupposition

4.3 Count noun construction

Count nouns in English have a "built-in" quantifier, require a numeral

(22) ⟦*fifty cows*⟧ = ⟦*cows*⟧(⟦*fifty*⟧)
= λnλx[NU(cow)(x) = n ∧ cow(x)](50)
= λx[NU(cow)(x) = 50 ∧ cow(x)]

* follows e.g. Krifka, Manfred. 1992. Thematic relations as links between nominal reference and temporal constitution. In: Sag, Ivan A. & Anna Szabolcsi, (eds), *Lexical Matters*. Stanford: CSLI, 29-53.

5 Measuring vs. Counting

5.1 Measuring

Different types of measure constructions:

- Container measures (container: count noun):

(23) *three glasses of beer, three baskets of apples*

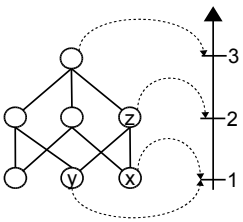
- Abstract measure units (usually no plural in German):

(24) *three liters of beer, three pounds of apples*

(25) *drei Liter Bier, drei Pfund / *Pfund-e Äpfel* (but: *drei Elle-n / *Elle Tuch*)

Based on extensive, additive measure function:

- If m(x) = n and y is a proper part of x, then m(y) < m(x)
- m(x⊕y) = m(x) + m(y), if x, y do not overlap



(26) ⟦*three liters of beer*⟧ = {x | beer(x) & liter(x) = 3}

Not possible with extensive measure functions:

(27) **thirty degrees Celsius of water*

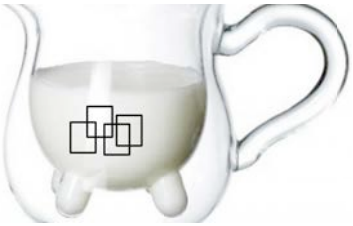
Proper measuring must result in quantized predicate:

- P is quantized iff for all x, y: If P(x) and P(y), then y cannot be a proper part of x.

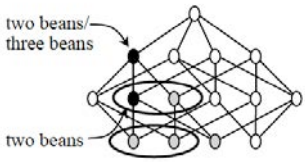
5.2 Counting and discreteness

Counting as a special type of measuring function c:

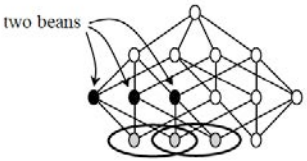
- Measure value 1 depends on general ontology or is specific to nominal property
  - c(x) = 1 iff x is an atom of the universe
  - c(x, apple) = 1 iff x counts as one w.r.t. the predicate ‘apple’, “natural units”
- This **standardizes** the counting function using a cognitively prominent phenomenon
- c is **generalized** by the requirement that it be an extensive measure function, i.e. $c(x \oplus y) = c(x)+c(y)$, if x, y do not overlap
- For this to work consistently, atoms must be **discrete** (non-overlapping), otherwise no consistent measuring possible



non-discrete:
how many distinct cubic inches of milk?



non-discrete base set



discrete base set

5.3 Similarity of atoms

A further criterion for atoms:

- Comparable criteria must be applied for atomhood
- This is sometimes difficult to achieve:

(28) *How many branches / twigs does this tree have?*

E.g.

- definition of *twig* as “terminal branch”,
- ad-hoc definition of *branch* as branch of comparable thickness at the base, comparable position in the tree, etc.

5.4 Spatial connection of atoms

Maximally connected entities:

- A mereotopological criterion, requiring the topological notion of connection
- An entity x is maximally connected iff any two pars y, z such that x = y⊕z are connected (Grimm 2012)
- A prominent systematic criterion for spatially extended entities.

How many lakes?

How many clouds?

5.5 Other criteria for atoms

Stability across time:

- Counting more useful if entities can be re-identified

Simple geometric shape:

- e.g. straight, round

Synchronous movement:

- objects, swarms

Causal connection:

- common origin
- causal connection

Discernability:

- Grain size

How many waves?

How many streets?

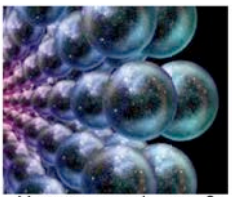
How many rivers?

How many swarms?

How many bacteria?

How many craters?

How many galaxies?



How many universes?

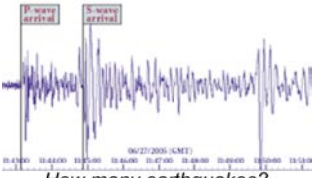
5.6 Event atoms and abstract atoms

Principle of maximal connectedness extends to non-spatial entities:

- temporal connectedness
- thematic connectedness, e.g. chapters, stories
- similarity, e.g. type / token distinction
- ability of having offspring, species
- ability of communicating, languages

Other connections in space of qualities

- types of behavior
- sense perception



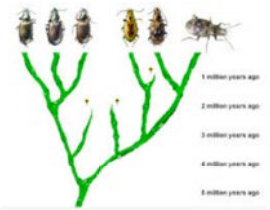
How many earthquakes?

Schneeseekleerehfehdrehzehwehtee
(Franz Fühmann)

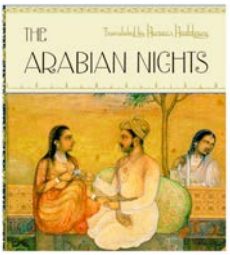
How many letters? 32 or 15?

How many colors?

How many sins?



How many species?



How many stories?

5.7 Phenomena that can be explained

Count nouns for “objects”, not for liquids

- that do not merge with other objects, do not evaporate, are temporally stable
- that are of a size and come with individual features such that they can be traced

Count nouns for animates, especially higher animates and humans (Smith-Stark 1974)

- Temporal continuity as organisms
- Constancy of shape in spite of material exchange (exception: metamorphosis)
- Goal-directed behavior that can be causally explained

Count nouns for shape, numeral classifiers that are shape-oriented

- shape nouns are generally count: *drop, circle, cube, rectangle, edge, corner...*
- mass nouns for substances that come in different shapes *gold, flour, pasta...*
- For liquids, containers can license counting, as they provide shape
- shape classifiers in Chinese,
  e.g. *tiao* for long objects (rivers, cigarettes), *ke* for kernel-like objects (beans, teeth)

5.8 Reasons for NOT identifying atoms

There are Landman's "neat" nouns that should be count.

Often, this can be motivated by different **frames** in which the nouns are used:

- *laundry* – for washing, individual pieces are less unimportant
- *mail* – sent and received in a batch vs. *letter* – inherent thematic unity
- *change* – used in transaction, individual pieces unimportant vs. *coins* – objects
- police – acts as a force with common purpose, individuals may be irrelevant
- *gold* vs. *nugget* – nuggets come in different sizes, do not have constant values
- *furniture* – "furnishes" a room, vs. German *Möbel* – movable objects
- *silverware* – consists of different subkinds like spoons, knives, forks that are count, but is used in various kinds of combination for serving food

But in questions like *Who has more furniture?*, relying on atoms is plausible (but not with, e.g., *Who has more change?)*

Mass / count and interaction

- Tendency for individual interaction with referents of count nouns, for collective interaction with referents of mass nouns (Middleton et.al. 2004*)

* Middleton, Erica L et al. 2004. Separating the chaff from the oats: Evidence for a conceptual distinction between count noun and mass noun aggregates. *Journal of Memory and Language* 50: 371-394.

6 Some more cases of counting

6.1 Counting verbal events

Events can be counted; counting principle: temporal, spatial, causal separation

(29) *two earthquakes, two wars, two hurricanes...*

Events reported by verbal predicates can be counted with a classifier construction*:

(30) *The light flashed three times*.

(31) *Wo qu-guo Xianggang* [*liang tang*]
1sg go-ASP Hong Kong two CL
'I went to Hong Kong two times'

Cf. corresponding cases of measure constructions:

(32) *The light flashed for three hours.*

There are no known cases of "count verbs", e.g.

(33) **The light flashed three.* vs. *The LED turns off after three flashings.*

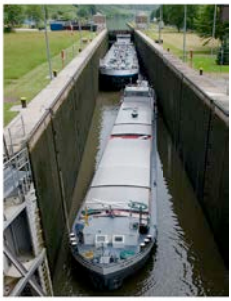
* Donazzan, Marta. 2012. On measuring and counting events. *Sinn und Bedeutung* 17.
Landman, F. (2006). Indefinite time-phrases, in situ-scope, and dual-perspective intensionality. In S. Vogeleer and L. Tasmowski (Eds.), *Non-definiteness and Plurality*, Amsterdam: John Benjamins.

6.2 Counting verbal events by participants

(34) a. *National Airlines served at least two million passengers in 1975*
b. *National Airlines served at least two million persons in 1975*

Gupta 1980 argues that *passengers* and *persons* are sortal nouns that have different criteria of identity:

- A person is a *passenger* during one trip
- A person can count as different passengers



Krifka 1990 points out that the distinction is not so clear-cut:

(35) a. *1200 persons walked through this turnstile yesterday.*
b. *4000 ships passed through the lock last year.*

Possible solution: Working with stages, Carlson 1977:

- *ship* can apply to ship obejcts or to ship stages (temporal slices)
- '4000 ship objects passed through the lock' – distinct objects
  '4000 ship stages passed through the lock' – one stage per lock passing

Problems:

- We have to count stages of the right (minimal) size
- We also have event-measuring mass nouns where stages are quite unclear:

(36) *Sixty tons of radioactive waste were transported through the lock last year*.

Krifka 1990 proposes instead:

- *4000 ships* can be constructed as an event measure function
- The atoms of this measure function are a single ship passing:
  e is an event of 1 ship passing iff there is 1 ship x, and e is a passing of x
- The measure function is generalized to multiple passings,
  as an extensive measure function:
  If e is an event of n ships passing,
  and e′ is an event of n′ ships passing,
  then e ⊕ e′ is an event of n + n′ ships passing, if e and e′ do not overlap
- As a consequence, *4000 ships* does not refer to 4000 distinct ships
- Anaphoric reference to the ships that passed (E-type pronoun):

(37) *4000 ships passed through the lock last year.*
Some of them carried radioactive waste.

- The approach can be extended to measure expressions:
  e is an event of n tons of radioactive waste passing if n tons of r. waste pass in e
  If e is an event of n tons of radioactive waste passing,
  and e′ is an event of n′ tons of radioactive waste passing,
  then e ⊕ e′ is an event of n + n′ tons of radioactive waste passing,
  if e and e′ do not overlap.

6.3 Counting concepts*

(38) *You have 3 shirts and 4 pairs of pants. How many different outfits can you make? [...] You get twelve outfits. Not counting if a dude makes an outfit without a shirt, or a crazy person without pants.*

(39) [Description of fischertechnik crane construction kit:]
100 Bauteile ermöglichen den Bau dreier unterschiedlicher, einfacher Kräne.
'With 100 construction parts one can build three different, simple cranes.'

Problem:

- You cannot dress 12 persons with 3 shirts and 4 pairs of pants
- You cannot built a setup with three cranes

* Krifka, Manfred. 2009. Counting configurations. In Arndt Riester & Torgrim Solstad (eds.), Proceedings of Sinn und Bedeutung 13, 309-324. U Stuttgart: SinSpeC.

Suggested solution:

- Nominal predicates are sortal concepts (Gupta) that map **individual concepts** to entities
- Individual concepts are functions from world/times to entities, e.g. *outfit* maps a world / time pair to the collection of a shirt and a pair of pants when worn together, as one outfit
- these individual concepts are distinct from each other, hence are proper atoms for counting functions,
  notice that even if shirt s_1 serves in distinct outfits, it never does so at the same world / time.

Example:

(40) *With two shirts and two pairs of pants, you have four outfits*.

- Assume you have shirts s1, s2 and pairs of pants p1, p2
- Four distinct outfits:
  o1 = λi. s1 and p1 are arranged as an outfit in i. [s1⊕p1]
  o2 = λi. s1 and p2 are arranged as an outfit in i. [s1⊕p2]
  o3 = λi. s2 and p1 are arranged as an outfit in i. [s2⊕p1]
  o4 = λi. s2 and p2 are arranged as an outfit in i. [s2⊕p2]
- *outfit* does not apply to individuals, but to concepts
- and, in a more elaborate theory, *shirt, pairs of pants* apply to concepts as well

7 Wrapping up

Number as a central semantic feature in the grammar of languages

- Number distinctions extremely frequent with personal pronouns
- Number distinction very frequent with nouns
- Mass noun / count noun distinction

Semantic rooting of measuring and counting

- measuring / counting: additive / extensive measure function
- counting: rooted in natural units (“atoms”) that are
- discrete and comparable
- based on maximal connectedness,
  temporal stability,
  synchronous movement
  causal connection
  discernability
- Non-count motivated by type of interaction, frames (e.g. *letters* / *mail*)
- Extension of object counting to counting events, to counting concepts