Introduction to Generative Lexicon[1]

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Sapienza Università di Roma
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[1] *Introduction to Generative Lexicon Theory*, Pustejovsky and Jezek (2020), Oxford University Press

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- Determination of the medium of the situation or event.

Decomposition Strategies: the early history

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5. Dowty (1972, 1979)

Lehrer’s Semantic Field of Factors

<table>
<tr><td colspan="14">cook$_1$</td><td>bake$_1$</td></tr>
<tr><td colspan="14">cook$_2$</td><td></td></tr>
<tr><td rowspan="3">steam</td><td colspan="4">boil$_1$</td><td colspan="2">fry</td><td colspan="3">broil</td><td></td><td>roast</td><td></td><td>bake$_2$</td><td></td></tr>
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French-fry</td><td>grill</td><td colspan="2">barbecue
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<tr><td>poach</td><td>stew</td><td>braise</td><td colspan="10"></td></tr>
</table>

Table 2.3: *Lexical field of cooking words*, Lehrer (1974)

Lehrer's Semantic Field of Factors

	Water	Oil or fat	Vapor	Amount of liquid	Kind of source of heat	Cooking action	Special utensil	Special additional purpose	Cooking speed
boil$_1$	+	-	-						
boil$_2$	+	-	-			[Vigorous]			
simmer	+	-	-			[Gentle]			
stew	+	-	-			[Gentle]		[To soften]	[Slow]
poach	+	-	-			[Gentle]		[To preserve shape]	
braise	+	+	-	[Small]			(Pot with lid)		
steam	+	-	+				(Rack, sieve)		
fry	-	+	*				(Frying pan)		
sauté	-	+	*	[Small]					[Fast]
French fry *deep fry*	-	+	*	[Large]					
broil	-	-	*	*	[Radiant]	*			
grill	-	-	*	*	[Radiant]	*	(Grill, griddle)		
barbecue *charcoal*	-	-	*	*	[Radiant (Hot coals)]	*			
bake	-	-	*	*	[Conducted]	*	(Oven)		
roast	-	-	*	*	[Radiant or conducted]	*			

Table 2.5: *Lexical field of cooking words, componential analysis*, Lehrer (1974)

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- Lexical meaning is fundamentally decompositional, i.e. based on the idea that words encode complex concepts that may be decomposed into simpler notions
- Decompositional processes are compositional in nature

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Pustejovsky 1995

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- Solution: (a) Distribute the components of meaning; (b) underspecify functional behavior:
  - Enrich the semantics of nouns: e.g., what doors, books, and bottles are for;
  - Encode what one does with an object: e.g., coffee, sandwich, movie;
  - Generalize the meaning of verbs: e.g., frying is a manner of cooking.

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  - $\lambda z.A(z)$
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1. a. John bought the new Obama book. (pure selection)
   b. John doesn't agree with the new Obama book. (inherent)
2. a. Mary left after her cigarette. (selection as coercion)
   b. Mary left after her smoking a cigarette. (pure selection)

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c. Complex types: Concepts integrating reference to a logical coherence relation between types from the other two levels.

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2. True Compositionality: Enrich the mechanisms of making larger meanings by taking advantage of all espressions in the phrase; type coercion, qualia exploitation, co-composition.

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ii. *Introduction*: wrapping the argument with the type required by the function.

Notation and Language: typed feature structures

$$
\begin{bmatrix}
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\text{EVENTSTR} = \begin{bmatrix} \text{EVENT1} = e1 \\ \text{EVENT2} = e2 \end{bmatrix} \\
\text{QUALIA} = \begin{bmatrix} \text{CONST} = \textbf{what } x \textbf{ is made of} \\ \text{FORMAL} = \textbf{what } x \textbf{ is} \\ \text{TELIC} = e_2\textbf{: function of } x \\ \text{AGENTIVE} = e_1\textbf{: how } x \textbf{ came into being} \end{bmatrix}
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- This is the standard way dictionaries and **resources** used for NLP tasks (i.e. WordNet for word sense detection etc.) are put together.

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Pustejovsky and Jezek 2012 *Introducing Qualia Stucture*

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- I bought the <u>flight</u> for Christmas.
- You reached the <u>house</u>.
- Do you want the whole <u>house</u> waken up?
- The rest of the <u>house</u> was sleeping.

Types of contextual variation

Contextual coercions

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Pustejovsky and Jezek 2008, Jezek and Quochi 2010, Pustejovsky et al. 2010 SemEval-2010 Task 7 Argument Selection and Coercion.

Types of contextual variations

Hidden Events

Types of contextual variations

Hidden Events

- We canceled the taxi.

Types of contextual variations

Hidden Events

- We canceled the <u>taxi</u>.
- From the house I heard the <u>bell</u>.

Types of contextual variations

Hidden Events

- We canceled the taxi.
- From the house I heard the bell.
- We took a break before dessert.

Types of contextual variations

Hidden Events

- We canceled the <u>taxi</u>.
- From the house I heard the <u>bell</u>.
- We took a break before <u>dessert</u>.
- They finished the <u>beer</u>.

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- We took a break before dessert.
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- Any chocolate? Not after that <u>cake</u>!

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Pustejovsky and Anick 1988 (later "Qualia roles"; data from Pustejovsky and Jezek 2012).

Types of contextual variations

Systematic polysemies (Apresjan 1973)

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- container/content

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- container/content
  - I broke two glasses.

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  - We had a quick and tasty lunch on the terrace.

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Cruse 1995's *nouns with facets*, Asher's 2011 *dual aspect nouns*.

Accounting for Missing Arguments

Fillmore (1985), Rappaport and Levin (1988), Jackendoff (1990), Levin (1993), Pustejovsky (1995), Goldberg (2002)

- John swept the dirt$_{material}$.
- John swept the room$_{region}$.

- The man shoveled the snow$_{material}$.
- The man shoveled the driveway$_{region}$.

- Mary translated the book. (the translation)
- They decorated the Christmas tree. (the decoration)
- Cathie sliced the bread. (slices)

Flexibility of Argument Interpretation 1/2

- That book bored me terribly.
- The movie frightened Mary.
- The newspaper article angered the Senator.

- The boy heard a cat.
- They heard a bang / rumor / rain.

- Mary believes the rumor.
- She never believes the newspaper.
- The student regrets his last homework assignment.

Flexibility of Argument Interpretation 2/2

- Mary began her beer / thesis / dinner / bath.
- John enjoyed his coffee / movie / a cigar.

- John knows that the earth is round.
- Mary knows what time it is.
- Mary knows the time.

- Mary told John where she lives.
- John told me how old he is.

- Mary told John her address.
- John told me his age.
- I just realized the time.

Context-sensitive model of lexical semantics

- **Semantic flexibility** is a property of natural language.
- The meaning of each word is expected to vary from occurrence to occurrence as a function of the interaction with the other words it combines with, and of the situation of utterance.
- **Functional notion** of polysemy.
- Generative Lexicon proposes that context-sensitivity is not confined to words with functional roles (traditionally verbs and adjectives), but extends e.g. to nouns (Pustejovsky's Qualia theory).
- Generative Lexicon spreads the semantic role to all items in the lexicon.

Evidence-based Language Analysis

- Linguistics is now both a theoretical and experimental discipline.
- The scope of observed data for language study and theorizing is richer and broader than ever.
- Linguistic Corpora and captured media datasets will enable contextualized and embodied interpretation of linguistic utterances.
- This will enable the development of more expressive and broader theories of language and communication.

Methods in Linguistics

- Sapir, Bloomfield, Hockett, Wells (Structural analysis)
  Discovery procedure allows for the emergence of grammatical patterns and constructions in a dataset.
- Chomsky, Bar-Hillel (Transformational Grammars)
  Descriptive procedure allows for the generation of grammatical patterns.
- Chomsky (Generative Grammar 1962- present)
  Explanatory model allows for the generation of best grammatical patterns.

1950-1990 - The Absence of Data

- Chomsky liberated the field of linguistics in the 1950s
- Generation through recursive functions allows one to create your own corpus
- Experiment with new datasets that are not attested in actual "found data"

1990-2017 - The Absence of Theory

- Big Data and statistical modeling have largely dominated the fields of CL and AI, both theoretical and applied.
- Deep Learning seems positioned to obviate theory completely.
- This will not happen: machine learning and deep learning make theoretical assumptions in both the data preparation and feature selection and engineering phase of training.
- Theory is more relevant than ever before.

Lexical Association Measures

- Pointwise Mutual Information:

$$\frac{\text{observed frequency}}{\text{expected frequency}} = PMI(A,B) = log_2 \frac{f_{AB}N}{f_A f_B}$$

- Association Score:

$$\text{AScore}(w_1, R, w_2) = log \frac{||w_1,R,w_2|| \cdot ||*,*,*||}{||w_1,R,*|| \cdot ||*,*,w_2||} \cdot log(||w_1, R, w_2|| + 1)$$

- t test:

$$\frac{\text{observed frequency - expected frequency}}{\sqrt{\text{expected frequency}}}$$

Corpus Analysis Toolkit – SketchEngine

- Corpus creating, loading, handling environment
- Allows extensive querying over the corpus and results of analysis
- Performs statistics and analytics over corpora
- https://www.sketchengine.co.uk/

Corpus Analysis Toolkit – SketchEngine

Sketch Engine | English Web 2013 (enTenTen13) | Prof. James Pustejovsk

- Home
- Search
- Word list
- Word sketch
- Thesaurus
- Sketch diff
- Corpus info
- My jobs
- User guide

- Save
- Change options
- Cluster
- Sort by freq
- Hide gramrels
- More data
- Less data

Menu position

read (verb)

English Web 2013 (enTenTen13) freq = 9,135,047 (401.91 per million)

modifiers of "read"	1,198,223	0.13
aloud +	19,777	9.01
read aloud		
somewhere +	13,428	8.14
I read somewhere that		
carefully +	16,764	8.04
carefully read		
please +	14,495	7.88
please read		
about +	65,599	7.75
read about		
ever +	38,541	7.54
've ever read		
recently +	21,144	7.36
I recently read		
widely +	10,650	7.30
widely read		
first +	18,088	7.26
I first read		
just +	101,055	7.08
just read		
here +	39,368	7.04
read here		
actually +	28,477	6.89
actually read		
below +	7,064	6.85
read below		
never +	29,207	6.35
never read		
then +	28,750	6.35

objects of "read"	3,463,987	0.38
book +	341,688	10.82
article +	232,787	10.57
post +	108,274	9.61
blog +	90,960	9.45
review +	85,830	9.36
rest +	65,241	9.02
. Read the rest of this entry		
story +	72,130	8.78
bible +	33,203	8.22
read the Bible		
comment +	39,167	8.19
report +	35,099	7.91
storey +	29,895	7.84
text +	27,936	7.83
page +	30,690	7.70
paper +	26,296	7.67
novel +	23,057	7.67
word +	35,736	7.66
label +	22,937	7.65
letter +	26,827	7.64
newspaper +	21,613	7.61
chapter +	18,873	7.35
magazine +	16,351	7.18
news +	19,248	7.18
email +	17,319	7.09
print +	14,975	7.07
read the fine print		
message +	19,379	7.02

subjects of "read"	707,028	0.08
anyone +	24,123	8.30
anyone reading		
continue +	4,469	7.68
... Continue reading the story "		
fun +	5,040	7.44
a fun read		
i +	35,227	7.27
i read		
ive +	3,945	7.26
Ive read		
reader +	4,812	7.09
everyone +	10,555	6.88
statement +	4,007	6.87
statement read .		
sign +	3,428	6.85
sign reads		
min +	2,586	6.85
mins reading time)		
people +	49,234	6.72
people read		
student +	10,469	6.61
students read		
someone +	9,520	6.60
time +	13,379	6.58
time reading		
headline +	2,149	6.55
headline reads		
hour +	3,438	6.52
hours reading		

"read" and/or ...	409,895	0.04
write +	68,986	11.34
read and write		
hear +	22,214	10.19
understand +	18,873	9.64
to read and understand		
watch +	11,027	9.27
listen +	10,004	9.13
study +	7,983	8.93
read and study		
see +	11,968	8.73
comment +	5,168	8.54
reading and commenting		
learn +	8,273	8.42
read and learn		
follow +	5,154	8.35
to read and follow		
speak +	5,126	8.22
discuss +	4,704	8.16
read and discuss		
enjoy +	4,837	8.00
read and enjoy		
interpret +	3,391	7.90
to read and interpret		
review +	3,856	7.86
to read and review		
sit +	4,026	7.81
to sit and read		
respond +	3,094	7.72
read and respond to		

prepositional phrases	615,601	
"read" about ...	136,992	0.01
"read" in ...	114,644	0.01
"read" through ...	54,402	0.01
"read" on ...	51,404	0.01
"read" from ...	36,399	0.00
"read" by ...	32,859	0.00
"read" for ...	30,399	0.00
"read" to ...	21,754	0.00
"read" at ...	21,572	0.00
"read" of ...	18,864	0.00
"read" with ...	18,105	0.00
"read" as ...	16,589	0.00
"read" like ...	15,533	0.00
"read" between ...	9,952	0.00
"read" over ...	8,752	0.00
"read" into ...	7,976	0.00
"read" during ...	2,639	0.00
"read" before ...	1,986	0.00
"read" so ...	1,355	0.00
"read" than ...	1,301	0.00
"read" without ...	1,232	0.00
"read" after ...	935	0.00
"read" below ...	751	0.00
"read" within ...	713	0.00
"read" until ...	600	0.00

SketchEngine | English Web 2013 (enTenTen13) | Elisabet

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read *(verb)*

English Web 2013 (enTenTen13) freq = 9,135,047 (401.91 per million)

Lemma	Score	Freq
write	0.515	9,209,491
learn	0.467	8,933,221
think	0.455	21,650,907
speak	0.441	4,829,660
talk	0.439	5,399,739
know	0.438	29,229,869
give	0.436	22,289,988
hear	0.434	6,078,870
present	0.429	3,390,837
tell	0.429	11,428,601
say	0.423	39,839,420
understand	0.422	6,215,980
want	0.413	21,635,056
receive	0.410	7,099,321
create	0.410	11,463,028
provide	0.410	16,231,340
see	0.410	29,777,567
need	0.407	21,424,720
like	0.406	8,924,162
make	0.405	51,256,256
show	0.404	10,492,472
mean	0.403	9,118,407
feel	0.403	12,463,798

Qualia Structure

- What is a Quale?
- What motivates Qualia?
- Default Qualia and context updating
- Methodology to identify Qualia
- Data for each Quale
- Qualia and Conventionalized Attributes
- Qualia and Type Systems

- Hume's cause: Counterfactual future (Agentive quale)

Moravcsik's 1975 interpretation of Aristotle's notion of *Aitia*

Causation as Understanding

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Causation as Understanding

- Hume's cause: Counterfactual future (Agentive quale)
- Projective cause: Telic quale
- Inherent cause: Constitutive quale
- Class distinction: Formal quale

Moravcsik's 1975 interpretation of Aristotle's notion of *Aitia*

What is a *Quale*?

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What is a *Quale*?

- A *Quale* (singular of *Qualia*) indicates **a single aspect of a word's meaning**, defined on the basis of the relation between the concept expressed by the word and another concept that the word evokes.
- Among the conceptual relations that a word may activate Qualia relations as defined in GL are those that are exploited in our understanding of linguistic expressions.
- *fresh bread* = "bread which has been baked recently."

Linguistic phenomena motivating Qualia relations

- Contextual modulations of noun meaning, due to the selecting predicate.
    - This car weighs over 2,000 lbs.

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  - You should warm your car up in winter.

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  - Did you lock the car?
  - The car screeched down the road.

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- Inference of implicit predicates from particular constructions.

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  - Verb-Noun combination: finish the <u>beer</u>/<u>cake</u>.

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  - fax a document.

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  - take a <u>train</u>.
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  - fax a <u>document</u>.
  - microwave the <u>chicken</u>.

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  - lace the <u>shoes</u>.

Linguistic phenomena motivating Qualia relations

- Short passives.

Linguistic phenomena motivating Qualia relations

- Short passives.
  - *This picture was painted.

Linguistic phenomena motivating Qualia relations

- Short passives.
    - *This picture was painted.
    - This picture was painted in 1604.

Linguistic phenomena motivating Qualia relations

- Short passives.
  - *This picture was painted.
  - This picture was painted in 1604.
- Middles.

Linguistic phenomena motivating Qualia relations

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  - This picture was painted in 1604.
- Middles.
  - *This book reads.

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  - This picture was painted in 1604.
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  - *This book reads.
  - This book reads easily.

Linguistic phenomena motivating Qualia relations

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  - *This <u>picture</u> was painted.
  - This <u>picture</u> was painted in 1604.
- Middles.
  - *This <u>book</u> reads.
  - This <u>book</u> reads easily.
- Adjectival Use of Past Participles.

Linguistic phenomena motivating Qualia relations

- Short passives.
  - *This <u>picture</u> was painted.
  - This <u>picture</u> was painted in 1604.
- Middles.
  - *This <u>book</u> reads.
  - This <u>book</u> reads easily.
- Adjectival Use of Past Participles.
  - *a built <u>house</u>.

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- Middles.
  - *This book reads.
  - This book reads easily.
- Adjectival Use of Past Participles.
  - *a built house.
  - a recently built house.

Decomposition in GL

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- Traditional decomposition frameworks fail to account for the semantic flexibility of words shown in the previous examples.
- GL draws insights about the meaning of a word by looking at the range of its contextual interpretations, and by examining how this range can be predictably derived from the underlying meanings.
- On this basis, the meaning is decomposed into the relevant features.

Qualia Relations or Roles

- Formal (F): encoding taxonomic information about the lexical item (the `is-a` relation);

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- Telic (T): encoding information on purpose and function (the *used-for* or `functions-as` relation);
- Agentive (A): encoding information about the origin of the object (the `created-by` relation).

Qualia Structure

$$\begin{bmatrix} \alpha & & \\ & & \\ \text{QUALIA} & = & \begin{bmatrix} \text{F} & = & \textbf{what } x \textbf{ is} \\ \text{C} & = & \textbf{what } x \textbf{ is made of} \\ \text{T} & = & \textbf{function of } x \\ \text{A} & = & \textbf{origin of } x \end{bmatrix} \end{bmatrix}$$

Qualia Structure

$$\begin{bmatrix} \textit{car} & \\ \text{QUALIA} = & \begin{bmatrix} \text{F} = \textbf{vehicle} \\ \text{C} = \textbf{engine, door, wheels,...} \\ \text{T} = \textbf{drive} \\ \text{A} = \textbf{build} \end{bmatrix} \end{bmatrix}$$

Methodology for identifying Qualia Values

- Linguistic evidence determines what information is stated to be lexically associated with the Qualia Structure of a word.

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- Pustejovsky and Jezek 2012.

Identifying Qualia Values

- The rock shattered the <u>window</u>.

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- ([T = live_in(human, building)])
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- $([\mathrm{F} =$ space$])$
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- ([C = water])
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Unspecified roles

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- Not all lexical items carry a value for each Q-role.
- Some values are left unspecified, while others are populated with more than one value.
- Nouns denoting natural kinds (e.g., *rock*, *fish*, *air*, *sea*) typically do not have a value for the A.

Default Quale and Context Updating

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- Unspecified Q-values may be introduced in context.

The Formal

- The Formal (F) encodes the relation between the entity denoted by the word and the category it belongs to.

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- The Formal (F) encodes the relation between the entity denoted by the word and the category it belongs to.
- This relation enables one to grasp the nature of an entity by discriminating it from other kinds.
- What type of entity is x denoting? *rock* denotes a natural kind, *table* denotes an artifact, *car* denotes a vehicle, *park* denotes a location, *water* denotes a liquid, *plant* denotes a living thing, *fish* denotes an animal, *hand* denotes a body part, *glass* denotes a container, and so on.

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- Classifications at different levels of generalization are available for reference:
- a liquid such as water.
- fluids such as water or air.
- substances such as fluids, salts, glucose and carbon dioxide.

Formal factors for the class of nouns denoting concrete entities

- Spatial characteristics, intrinsic orientation.

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- Size and dimensional properties.

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- Size and dimensional properties.
- Shape and form.

Formal factors for the class of nouns denoting concrete entities

- Spatial characteristics, intrinsic orientation.
- Size and dimensional properties.
- Shape and form.
- Color.

Formal factors for the class of nouns denoting concrete entities

- Spatial characteristics, intrinsic orientation.
- Size and dimensional properties.
- Shape and form.
- Color.
- Position.

Formal factors for the class of nouns denoting concrete entities

- Spatial characteristics, intrinsic orientation.
- Size and dimensional properties.
- Shape and form.
- Color.
- Position.
- Surface.

Values for Formal factors of nouns denoting concrete entities

- a red <u>car</u>

Values for Formal factors of nouns denoting concrete entities

- a red car
- (Color$_F$)

Values for Formal factors of nouns denoting concrete entities

- a red <u>car</u>
- (Color_F)
- a long <u>dress</u>

Values for Formal factors of nouns denoting concrete entities

- a red <u>car</u>
- (Color_F)
- a long <u>dress</u>
- (Dimension_F)

Values for Formal factors of nouns denoting concrete entities

- a red <u>car</u>
- (Color_F)
- a long <u>dress</u>
- (Dimension_F)
- a round <u>table</u>

Values for Formal factors of nouns denoting concrete entities

- a red car
- (Color_F)
- a long dress
- (Dimension_F)
- a round table
- (Shape_F)

Values for Formal factors of nouns denoting concrete entities

- a red <u>car</u>
- (Color_F)
- a long <u>dress</u>
- ($\mathrm{Dimension}_F$)
- a round <u>table</u>
- (Shape_F)
- a red <u>pen</u>

Values for Formal factors of nouns denoting concrete entities

- a red <u>car</u>
- (Color$_F$)
- a long <u>dress</u>
- (Dimension$_F$)
- a round <u>table</u>
- (Shape$_F$)
- a red <u>pen</u>
- (Color$_F$) or T/C (depending on contextual interpretation)

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- a red <u>car</u>
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- (Shape$_F$)
- a red <u>pen</u>
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- a flat <u>screen</u>

Values for Formal factors of nouns denoting concrete entities

- a red <u>car</u>
- (Color_F)
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- (Dimension_F)
- a round <u>table</u>
- (Shape_F)
- a red <u>pen</u>
- (Color_F) or T/C (depending on contextual interpretation)
- a flat <u>screen</u>
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- a red <u>car</u>
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- (Shape$_F$)
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- a flat <u>screen</u>
- (Shape$_F$)
- a thick <u>sweater</u>

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- a red car
- (Color$_F$)
- a long dress
- (Dimension$_F$)
- a round table
- (Shape$_F$)
- a red pen
- (Color$_F$) or T/C (depending on contextual interpretation)
- a flat screen
- (Shape$_F$)
- a thick sweater
- (Dimension$_F$)

Values for Formal factors of nouns denoting concrete entities

- the lenght of the <u>table</u>

Values for Formal factors of nouns denoting concrete entities

- the lenght of the table
- (Dimension$_F$)

Values for Formal factors of nouns denoting concrete entities

- the lenght of the <u>table</u>
- (Dimension$_F$)
- the facade of the <u>building</u>

Values for Formal factors of nouns denoting concrete entities

- the lenght of the table
- (Dimension$_F$)
- the facade of the building
- (Orientation$_F$)

Values for Formal factors of nouns denoting concrete entities

- the lenght of the <u>table</u>
- (Dimension$_F$)
- the facade of the <u>building</u>
- (Orientation$_F$)
- wipe the <u>floor</u>

Values for Formal factors of nouns denoting concrete entities

- the lenght of the <u>table</u>
- (Dimension$_F$)
- the facade of the <u>building</u>
- (Orientation$_F$)
- wipe the <u>floor</u>
- (Surface$_F$)

Values for Formal factors of nouns denoting concrete entities

- the lenght of the <u>table</u>
- (Dimension$_F$)
- the facade of the <u>building</u>
- (Orientation$_F$)
- wipe the <u>floor</u>
- (Surface$_F$)
- a large round <u>table</u>

Values for Formal factors of nouns denoting concrete entities

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- the facade of the <u>building</u>
- (Orientation$_F$)
- wipe the <u>floor</u>
- (Surface$_F$)
- a large round <u>table</u>
- (Size$_F$) (Shape$_F$)

Values for Formal factors of nouns denoting concrete entities

- the lenght of the table
- (Dimension$_F$)
- the facade of the building
- (Orientation$_F$)
- wipe the floor
- (Surface$_F$)
- a large round table
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Formal-specific Constructions

- NP *such as* NP: *events such as lectures, walks, tours and meetings*;

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- NP, *including* NP: *recyclable materials including glass*;
- NP, *especially* NP: *cool temperate countries especially Europe and North America*;
- *favorite* NP is NP: *Mario's favorite food is pasta.*

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The Constitutive Quale

- The Constitutive (C) role encodes information about what is “inside” the object denoted by the word, particularly the material the object is made of (i.e., its stuff), and the parts it consists of.
- There is a fundamental distinction between inherently individuated things, such as humans, tigers, and trees, and inherently undifferentiated stuff, such as water, air, and sand.
- This is reflected in the count vs. mass distinction in linguistics.

Count Nouns and Mass nouns in GL

COUNT NOUN: (where $\alpha \neq \beta$).

$$\begin{bmatrix} \textbf{N} & \\ \text{QUALIA} = & \begin{bmatrix} \text{F} = \alpha \\ \text{C} = \beta \end{bmatrix} \end{bmatrix}$$

MASS NOUN:

$$\begin{bmatrix} \textbf{N} & \\ \text{QUALIA} = & \begin{bmatrix} \text{F} = \alpha \\ \text{C} = \alpha \end{bmatrix} \end{bmatrix}$$

The Formal-Constitutive Equivalence Constraint for mass nouns in GL

$$\begin{bmatrix} \textit{water} \\ \text{QUALIA} = \begin{bmatrix} \text{F}/\text{C} = \textbf{liquid} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \textit{rock} \\ \text{QUALIA} = \begin{bmatrix} \text{F}/\text{C} = \textbf{solid\_substance} \end{bmatrix} \end{bmatrix}$$

but cf.

$$\begin{bmatrix} \textit{rock} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{solid\_object} \\ \text{C} = \textbf{solid\_substance} \end{bmatrix} \end{bmatrix}$$

Default values for MADE-OF relation in C

- The river had frozen during the severe weather.

$$\begin{bmatrix} \textit{river} & \\ \text{QUALIA} = & \begin{bmatrix} \text{F} = \textbf{space} \\ \text{C} = \textbf{water} \end{bmatrix} \end{bmatrix}$$

Default values for MADE-OF relation in C

- The river had frozen during the severe weather.
- ([C = water])

$$\begin{bmatrix} \textit{river} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{space} \\ \text{C} = \textbf{water} \end{bmatrix} \end{bmatrix}$$

Default values for MADE-OF relation in C

- The river had frozen during the severe weather.
- ([C = water])
- The river became polluted.

$$\begin{bmatrix} \textit{river} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{space} \\ \text{C} = \textbf{water} \end{bmatrix} \end{bmatrix}$$

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- The river had frozen during the severe weather.
- ([C = water])
- The river became polluted.
- ([C = water])
- the banks of a polluted river.

$$\begin{bmatrix} \textit{river} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{space} \\ \text{C} = \textbf{water} \end{bmatrix} \end{bmatrix}$$

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MADE-OF RELATION introduced in composition

- Nominal compounding
  - plastic bag

MADE-OF RELATION introduced in composition

- Nominal compounding
  - plastic bag
  - paper cup

MADE-OF RELATION introduced in composition

- Nominal compounding
  - plastic bag
  - paper cup
  - leather shoes

MADE-OF RELATION introduced in composition

- Nominal compounding
  - plastic bag
  - paper cup
  - leather shoes
  - gold watch

MADE-OF RELATION introduced in composition

- Nominal compounding
  - plastic bag
  - paper cup
  - leather shoes
  - gold watch
  - milk chocolate

MADE-OF RELATION introduced in composition

- Adjective-Noun constructions
  - a golden ring

MADE-OF RELATION introduced in composition

- Adjective-Noun constructions
  - a golden ring
  - a wooden floor

MADE-OF RELATION introduced in composition

- Adjective-Noun constructions
  - a golden ring
  - a wooden floor
  - a metallic paint

Constitutive-specific construction

- N_1's N_2: *the room's wall*.

Constitutive-specific construction

- N_1's N_2: *the room's wall*.
- N_2 of N_1: *the door of the car*.

Constitutive-specific construction

- N_1's N_2: *the room's wall*.
- N_2 of N_1: *the door of the car*.
- NP_2 is a part of NP_2: *brain is a very sensitive part of the body*.

Constitutive-specific construction

- N_1's N_2: *the room's wall*.
- N_2 of N_1: *the door of the car*.
- NP_2 is a part of NP_2: *brain is a very sensitive part of the body*.
- NP_1 made of NP_2: *monuments made of stone and marble*.

Constitutive-specific construction

- N_1's N_2: *the room's wall*.
- N_2 of N_1: *the door of the car*.
- NP_2 is a part of NP_2: *brain is a very sensitive part of the body*.
- NP_1 made of NP_2: *monuments made of stone and marble*.
- NP_1 of NP_2: *house of wood*.

Constitutive-specific construction

- N_1's N_2: *the room's wall*.
- N_2 of N_1: *the door of the car*.
- NP_2 is a part of NP_2: *brain is a very sensitive part of the body*.
- NP_1 made of NP_2: *monuments made of stone and marble*.
- NP_1 of NP_2: *house of wood*.
- NP_1 consists of NP_2: *the orchestra consists of ninety performers*.

Constitutive-specific construction

- N_1's N_2: *the room's wall*.
- N_2 of N_1: *the door of the car*.
- NP_2 is a part of NP_2: *brain is a very sensitive part of the body*.
- NP_1 made of NP_2: *monuments made of stone and marble*.
- NP_1 of NP_2: *house of wood*.
- NP_1 consists of NP_2: *the orchestra consists of ninety performers*.
- NP_1 containing NP_2: *a forest containing dead trees*.

Hidden events and the Telic

- The Telic relation (T) encodes information about the intended use or function of an object.

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Hidden events and the Telic

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Hidden events and the Telic

- The Telic relation (T) encodes information about the intended use or function of an object.
- It expresses the relation that allows us to grasp what an entity is by knowing what it is used for.
- It encodes a potential activity of the object.
- First sistematic mention of Telic in Pustejovsky and Anick (1988) as hidden event.

Default values for Telic relation

- Any chocolate? Not after that cake!

Default values for Telic relation

- Any chocolate? Not after that cake!
- ($[\mathrm{T} = \text{eat}]$)

Default values for Telic relation

- Any chocolate? Not after that cake!
- ($[\text{T} = $ eat$]$)
- I prefer cake to biscuits.

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.

Default values for Telic relation

- Any chocolate? Not after that cake!
- ($[\mathrm{T} = \text{eat}]$)
- I prefer cake to biscuits.
- ($[\mathrm{T} = \text{eat}]$)
- We skipped the cake and settled for another coffee.
- ($[\mathrm{T} = \text{eat}]$)

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.
- ([T = eat])
- the next customer.

Default values for Telic relation

- Any chocolate? Not after that cake!
- $([\mathrm{T} = \text{eat}])$
- I prefer cake to biscuits.
- $([\mathrm{T} = \text{eat}])$
- We skipped the cake and settled for another coffee.
- $([\mathrm{T} = \text{eat}])$
- the next customer.
- $([\mathrm{T} = \text{take\_care\_of}])$

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.
- ([T = eat])
- the next customer.
- ([T = take_care_of])
- the next slide.

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.
- ([T = eat])
- the next customer.
- ([T = take_care_of])
- the next slide.
- ([T = project])

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.
- ([T = eat])
- the next customer.
- ([T = take_care_of])
- the next slide.
- ([T = project])
- This is a difficult problem.

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.
- ([T = eat])
- the next customer.
- ([T = take_care_of])
- the next slide.
- ([T = project])
- This is a difficult problem.
- ([T = solve])

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.
- ([T = eat])
- the next customer.
- ([T = take_care_of])
- the next slide.
- ([T = project])
- This is a difficult problem.
- ([T = solve])
- This is a difficult question.

Default values for Telic relation

- Any chocolate? Not after that cake!
- ([T = eat])
- I prefer cake to biscuits.
- ([T = eat])
- We skipped the cake and settled for another coffee.
- ([T = eat])
- the next customer.
- ([T = take_care_of])
- the next slide.
- ([T = project])
- This is a difficult problem.
- ([T = solve])
- This is a difficult question.
- ([T = solve])

Updating Telic values in composition

When the Telic activity being expressed does not correspond to the Telic value specified in the noun, we say that the expression updates the Telic information associated with the noun in composition.

$$\begin{bmatrix} \textit{shopping bag} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{container} \\ \text{T} = \textbf{shopping} \end{bmatrix} \end{bmatrix}$$

Telic-specific constructions

- an NP to V: *a book to read*.

Telic-specific constructions

- an NP to V: *a book to read*.
- an NP worth V-ing: *a question worth asking*.

Telic-specific constructions

- an NP to V: *a book to read*.
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- the NP merits/deserves V-ing: *This book deserves reading.*.

Telic-specific constructions

- an NP to V: *a book to read*.
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- enjoy/prefer V-ing NP: *enjoy listening to music / prefer watching television*.

Telic-specific constructions

- an NP to V: *a book to read*.
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Telic-specific constructions

- an NP to V: *a book to read*.
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- the NP merits/deserves V-ing: *This book deserves reading.*.
- enjoy/prefer V-ing NP: *enjoy listening to music / prefer watching television*.
- an Adj NP to V: *a difficult question to ask*.
- an NP (used) for V-ing: *a spade (used) for digging*.

- The Telic of a natural kind (T_N), (*human*, *dog*, *water*, and so forth) encodes information about the actions and properties that the object engages in, but that are not intentional or purposive.

A *river* does not intentionally flow, but this is a necessary property of a body of water if it is to qualify as a river (as in a fast / rapid / slow / lazy river).

$$\begin{bmatrix} \textit{river} & \\ \text{QUALIA} = & \begin{bmatrix} \text{F} = \textbf{space} \\ \text{C} = \textbf{water} \\ \text{T}_{N} = \textbf{flow} \end{bmatrix} \end{bmatrix}$$

The Agentive

- The Agentive quale (A) encodes information about the origin of the object denoted by N.
- It provides a mechanism for discriminating those objects that present themselves to us (occurring naturally) from the various artifacts that we create through our own activities and intentional behavior.
- Differently from the value of T, A introduces an existentially bound or existentially quantified event, that precedes the existence of the object.

Agentive-Telic Pairing

- Inherent in this is an association between the Agentive and Telic of the object, i.e., the object is made for a purpose (Agentive-Telic pairing).
- Natural kinds lack this association, as they do not encode an Agentive value.

Default values for Agentive

- He just finished and published his first novel.

Default values for Agentive

- He just finished and published his first <u>novel</u>.
- ([A = write])

Default values for Agentive

- He just finished and published his first <u>novel</u>.
- ([A = write])
- Woody Allen has started a new <u>movie</u>.

Default values for Agentive

- He just finished and published his first novel.
- ([A = write])
- Woody Allen has started a new movie.
- ([A = direct, film])

Default values for Agentive

- He just finished and published his first <u>novel</u>.
- ([A = write])
- Woody Allen has started a new <u>movie</u>.
- ([A = direct, film])
- John began a large <u>oil painting</u> yesterday.

Default values for Agentive

- He just finished and published his first novel.
- ([A = write])
- Woody Allen has started a new movie.
- ([A = direct, film])
- John began a large oil painting yesterday.
- ([A = paint])

Default values for Agentive

- He just finished and published his first novel.
- ([A = write])
- Woody Allen has started a new movie.
- ([A = direct, film])
- John began a large oil painting yesterday.
- ([A = paint])
- Mary made a cake.

Default values for Agentive

- He just finished and published his first <u>novel</u>.
- ([A = write])
- Woody Allen has started a new <u>movie</u>.
- ([A = direct, film])
- John began a large <u>oil painting</u> yesterday.
- ([A = paint])
- Mary made a <u>cake</u>.
- ([A = bake)

Default values for Agentive

- He just finished and published his first novel.
- ([A = write])
- Woody Allen has started a new movie.
- ([A = direct, film])
- John began a large oil painting yesterday.
- ([A = paint])
- Mary made a cake.
- ([A = bake)
- Her mother made her a dress.

Default values for Agentive

- He just finished and published his first novel.
- ([A = write])
- Woody Allen has started a new movie.
- ([A = direct, film])
- John began a large oil painting yesterday.
- ([A = paint])
- Mary made a cake.
- ([A = bake)
- Her mother made her a dress.
- ([A = sew])

Default values for Agentive

- He just finished and published his first novel.
- ([A = write])
- Woody Allen has started a new movie.
- ([A = direct, film])
- John began a large oil painting yesterday.
- ([A = paint])
- Mary made a cake.
- ([A = bake)
- Her mother made her a dress.
- ([A = sew])
- fresh coffee

Default values for Agentive

- He just finished and published his first <u>novel</u>.
- ([A = write])
- Woody Allen has started a new <u>movie</u>.
- ([A = direct, film])
- John began a large <u>oil painting</u> yesterday.
- ([A = paint])
- Mary made a <u>cake</u>.
- ([A = bake)
- Her mother made her a <u>dress</u>.
- ([A = sew])
- fresh <u>coffee</u>
- ([A = brew])

Default values for Agentive

- He just finished and published his first novel.
- ([A = write])
- Woody Allen has started a new movie.
- ([A = direct, film])
- John began a large oil painting yesterday.
- ([A = paint])
- Mary made a cake.
- ([A = bake)
- Her mother made her a dress.
- ([A = sew])
- fresh coffee
- ([A = brew])
- fresh water

Default values for Agentive

- He just finished and published his first novel.
- ($[\mathrm{A}$ = write$]$)
- Woody Allen has started a new movie.
- ($[\mathrm{A}$ = direct, film$]$)
- John began a large oil painting yesterday.
- ($[\mathrm{A}$ = paint$]$)
- Mary made a cake.
- ($[\mathrm{A}$ = bake)
- Her mother made her a dress.
- ($[\mathrm{A}$ = sew$]$)
- fresh coffee
- ($[\mathrm{A}$ = brew$]$)
- fresh water
- (in contrast to "salt water")

Artifactual Types with an Agentive (coffee)

$$\begin{bmatrix} \textit{water/coffee} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{liquid} \\ \text{T} = \textbf{drink} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \textit{coffee} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{liquid} \\ \text{T} = \textbf{drink} \\ \text{A} = \textbf{brew} \end{bmatrix} \end{bmatrix}$$

CA and conventionalized commonsense knowledge

- A conventionalized attribute (CA) is a property typically associated with an object through our experiencing of it.

CA and conventionalized commonsense knowledge

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CA and conventionalized commonsense knowledge

- A conventionalized attribute (CA) is a property typically associated with an object through our experiencing of it.
- Only the most conventional activities associated with an object are coded in the noun's meaning as CAs.
- They can be identified through empirical testing.

CA and conventionalized commonsense knowledge

$$\begin{bmatrix} \textit{competition} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{event} \\ \text{C} = \textbf{rules} \\ \text{T} = \textbf{win} \\ \text{A} = \textbf{oppositional\_activity(x,y)} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \textit{game} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{competition} \\ \text{C} = \textbf{rules} \\ \text{T} = \textbf{pleasure} \\ \text{A} = \textbf{oppositional\_activity(x,y)} \end{bmatrix} \end{bmatrix}$$

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.
- ([$\textsc{sound}$ = barking])

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.
- ([SOUND = barking])
- Ann was listening to the <u>birds</u>.

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.
- ([SOUND = barking])
- Ann was listening to the <u>birds</u>.
- ([SOUND = singing])

Conventionalized Attributes

- They heard the village dog in the distance.
- ([SOUND = barking])
- Ann was listening to the birds.
- ([SOUND = singing])
- He could hear the rain in the garden.

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.
- ([SOUND = barking])
- Ann was listening to the <u>birds</u>.
- ([SOUND = singing])
- He could hear the <u>rain</u> in the garden.
- ([SOUND = falling])

Conventionalized Attributes

- They heard the village dog in the distance.
- ([SOUND = barking])
- Ann was listening to the birds.
- ([SOUND = singing])
- He could hear the rain in the garden.
- ([SOUND = falling])
- John can smell the flowers in his garden.

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.
- ([SOUND = barking])
- Ann was listening to the <u>birds</u>.
- ([SOUND = singing])
- He could hear the <u>rain</u> in the garden.
- ([SOUND = falling])
- John can smell the <u>flowers</u> in his garden.
- ([SMELL = scent])

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.
- ([SOUND = barking])
- Ann was listening to the <u>birds</u>.
- ([SOUND = singing])
- He could hear the <u>rain</u> in the garden.
- ([SOUND = falling])
- John can smell the <u>flowers</u> in his garden.
- ([SMELL = scent])
- The repairman smelled <u>gas</u> in the kitchen.

Conventionalized Attributes

- They heard the village <u>dog</u> in the distance.
- ([SOUND = barking])
- Ann was listening to the <u>birds</u>.
- ([SOUND = singing])
- He could hear the <u>rain</u> in the garden.
- ([SOUND = falling])
- John can smell the <u>flowers</u> in his garden.
- ([SMELL = scent])
- The repairman smelled <u>gas</u> in the kitchen.
- ([SMELL = odor])

Conventionalized Attributes

- They heard the village dog in the distance.
- ([SOUND = barking])
- Ann was listening to the birds.
- ([SOUND = singing])
- He could hear the rain in the garden.
- ([SOUND = falling])
- John can smell the flowers in his garden.
- ([SMELL = scent])
- The repairman smelled gas in the kitchen.
- ([SMELL = odor])
- Mary woke up and smelled coffee.

Conventionalized Attributes

- They heard the village dog in the distance.
- ([SOUND = barking])
- Ann was listening to the birds.
- ([SOUND = singing])
- He could hear the rain in the garden.
- ([SOUND = falling])
- John can smell the flowers in his garden.
- ([SMELL = scent])
- The repairman smelled gas in the kitchen.
- ([SMELL = odor])
- Mary woke up and smelled coffee.
- ([SMELL = aroma])

Conventionalized Attributes

- Mary sat out and enjoyed the sun.

Conventionalized Attributes

- Mary sat out and enjoyed the <u>sun</u>.
- ([CA = warming up])

Conventionalized Attributes

- Mary sat out and enjoyed the <u>sun</u>.
- ([CA = warming up])
- It's a great place to enjoy the <u>sea</u>.

Conventionalized Attributes

- Mary sat out and enjoyed the sun.
- ([CA = warming up])
- It's a great place to enjoy the sea.
- ([CA = viewing, swimming, walking])

Conventionalized Attributes

- Mary sat out and enjoyed the sun.
- ($[\mathrm{CA} =$ warming up$]$)
- It's a great place to enjoy the sea.
- ($[\mathrm{CA} =$ viewing, swimming, walking$]$)
- The tuna is one of the fastest fish in the sea.

Conventionalized Attributes

- Mary sat out and enjoyed the <u>sun</u>.
- ([CA = warming up])
- It's a great place to enjoy the <u>sea</u>.
- ([CA = viewing, swimming, walking])
- The tuna is one of the fastest <u>fish</u> in the sea.
- ([CA = swimming])

Conventionalized Attributes

- Mary sat out and enjoyed the <u>sun</u>.
- ([CA = warming up])
- It's a great place to enjoy the <u>sea</u>.
- ([CA = viewing, swimming, walking])
- The tuna is one of the fastest <u>fish</u> in the sea.
- ([CA = swimming])
- John was the fastest <u>boy</u> in the school.

Conventionalized Attributes

- Mary sat out and enjoyed the sun.
- ($[\mathrm{CA}=$ warming up$]$)
- It's a great place to enjoy the sea.
- ($[\mathrm{CA}=$ viewing, swimming, walking$]$)
- The tuna is one of the fastest fish in the sea.
- ($[\mathrm{CA}=$ swimming$]$)
- John was the fastest boy in the school.
- ($[\mathrm{CA}=$ running$]$)

Conventionalized Attributes

- Mary sat out and enjoyed the sun.
- ([CA $=$ warming up])
- It's a great place to enjoy the sea.
- ([CA $=$ viewing, swimming, walking])
- The tuna is one of the fastest fish in the sea.
- ([CA $=$ swimming])
- John was the fastest boy in the school.
- ([CA $=$ running])
- I could hear a car behind me.

Conventionalized Attributes

- Mary sat out and enjoyed the sun.
- ([CA = warming up])
- It's a great place to enjoy the sea.
- ([CA = viewing, swimming, walking])
- The tuna is one of the fastest fish in the sea.
- ([CA = swimming])
- John was the fastest boy in the school.
- ([CA = running])
- I could hear a car behind me.
- ([CA = driving])

Conventionalized Attributes

- Mary sat out and enjoyed the sun.
- ([CA = warming up])
- It's a great place to enjoy the sea.
- ([CA = viewing, swimming, walking])
- The tuna is one of the fastest fish in the sea.
- ([CA = swimming])
- John was the fastest boy in the school.
- ([CA = running])
- I could hear a car behind me.
- ([CA = driving])
- We do occasionally hear an airplane.

Conventionalized Attributes

- Mary sat out and enjoyed the <u>sun</u>.
- ([CA = warming up])
- It's a great place to enjoy the <u>sea</u>.
- ([CA = viewing, swimming, walking])
- The tuna is one of the fastest <u>fish</u> in the sea.
- ([CA = swimming])
- John was the fastest <u>boy</u> in the school.
- ([CA = running])
- I could hear a <u>car</u> behind me.
- ([CA = driving])
- We do occasionally hear an <u>airplane</u>.
- ([CA = flying])

CAs as projective manifestations of Qualia

- CAs in GL are interpreted as projective manifestations of specific Qualia.

CAs as projective manifestations of Qualia

- CAs in GL are interpreted as projective manifestations of specific Qualia.
- The representation of CAs in GL is always mediated through a Quale.

Projective operations over T values

- There's no train till 7:00 pm.

Projective operations over T values

- There's no train till 7:00 pm.
- (there is no departing)

Projective operations over T values

- There's no train till 7:00 pm.
- (there is no departing)
- The train was delayed for an hour.

Projective operations over T values

- There's no train till 7:00 pm.
- (there is no departing)
- The train was delayed for an hour.
- (the departure was delayed)

Projective operations over T values

- There's no train till 7:00 pm.
- (there is no departing)
- The train was delayed for an hour.
- (the departure was delayed)
- I left in time to catch the early train.

Projective operations over T values

- There's no train till 7:00 pm.
- (there is no departing)
- The train was delayed for an hour.
- (the departure was delayed)
- I left in time to catch the early train.
- (departing early)

Projective operations over T values

- There's no train till 7:00 pm.
- (there is no departing)
- The train was delayed for an hour.
- (the departure was delayed)
- I left in time to catch the early train.
- (departing early)
- Heavy foods such as dairy products and meat.

Representation of Conventionalized Attributes

$$\begin{bmatrix} \textit{dog} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \begin{bmatrix} \text{F} = \textbf{animal} \\ \text{CA} = \textbf{bark} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \textit{fish} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \begin{bmatrix} \text{F} = \textbf{animal} \\ \text{CA} = \textbf{live\_in(water), swim} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \textit{car} \\ \text{QUALIA} = \begin{bmatrix} \text{F} = \textbf{vehicle} \\ \text{T} = \begin{bmatrix} \text{T} = \textbf{drive} \\ \text{CA} = \textbf{make\_noise} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Type Composition Logic (Asher and Pustejovsky, 2006)

1. e the general type of entities; t the type of truth values.
   (σ, τ range over all simple types, and subtypes of e.)
2. If σ and τ are types, then so is $\sigma \rightarrow \tau$.
3. If σ and τ are types, then so is $\sigma \otimes_R \tau$; R ranges over A or T.
4. If σ and τ are types, then so is $\sigma \bullet \tau$.

Qualia Types

$$\begin{bmatrix} x: & & \alpha \\ & \otimes_c & \beta \\ & \otimes_t & \tau \\ & \otimes_a & \sigma \end{bmatrix}$$

with an unlabeled qualia value

$$\begin{bmatrix} x: & & \alpha \\ & \otimes & \tau \\ & & \end{bmatrix}$$

Natural Types

Entities formed from the application of the FORMAL and/or CONST qualia roles:

1. For the predicates below, e_N is structured as a join semi-lattice, $\langle e_N, \sqsubseteq \rangle$;
2. *physical, human, stick, lion, pebble*
3. *water, sky, rock*

Natural Predicate Types

Predicates formed with Natural Entities as arguments:

1. *fall*: $e_N \rightarrow t$
2. *touch*: $e_N \rightarrow (e_N \rightarrow t)$
3. *be under*: $e_N \rightarrow (e_N \rightarrow t)$

a. $\lambda x{:}e_N[\ \mathit{fall}(\mathrm{x})]$

b. $\lambda y{:}e_N \lambda x{:}e_N[\ \mathit{touch}(\mathrm{x,y})]$

c. $\lambda y{:}e_N \lambda x{:}e_N[\ \mathit{be\text{-}under}(\mathrm{x,y})]$

Artifactual Entity Types

Entities formed from the Naturals by adding the AGENTIVE or TELIC qualia roles:

1. Artifact Entity: $x : e_N \otimes_a \sigma$
   x exists because of event σ
2. Functional Entity: $x : e_N \otimes_t \tau$
   the purpose of x is τ
3. Functional Artifactual Entity: $x : (e_N \otimes_a \sigma) \otimes_t \tau$
   x exists because of event σ for the purpose τ

a. *beer*: $(liquid \otimes_a brew) \otimes_t drink$

b. *knife*: $(phys \otimes_a make) \otimes_t cut$

c. *house*: $(phys \otimes_a build) \otimes_t live\_in$

Artifactual Predicate Types

Predicates formed with Artifactual Entities as arguments:

1. *spoil*: $e_N \otimes_t \tau \rightarrow t$
2. *fix*: $e_N \otimes_t \tau \rightarrow (e_N \rightarrow t)$

a. $\lambda x{:}e_A[\ spoil(\mathrm{x})]$
b. $\lambda y{:}e_A \lambda x{:}e_N[\ fix(\mathrm{x,y})]$

- The beer spoiled.
- Mary fixed the watch.

Complex Entity Types

Entities formed from the Naturals and Artifactuals by a product type between the entities, i.e., the dot, $\bullet$.

1. a. Mary doesn't believe the book.
   b. John sold his book to Mary.
2. a. The exam started at noon.
   b. The students could not understand the exam.

Motivating Dot Objects

When a single word or phrase has the ability to appear in selected contexts that are contradictory in type specification.

If a lexical expression, α, where $\sigma \sqcap \tau = \perp$:

1. [___] $_\sigma$ X
2. [___] $_\tau$ Y

are both well-formed predications, then α is a dot object (complex type).

Dot Object Inventory: 1

1. Act•Proposition: promise, allegation, lie
   - I doubt John's promise of marriage.
   - John's promise of marriage happened while we were in Prague.
2. Attribute•Value: temperature, weight, height, tension, strength
   - The temperature is rising.
   - The temperature is 23.

Dot Object Inventory: 2

1. Event•Information: lecture, play, seminar, exam, quiz, test

   a. My lecture lasted an hour.
   b. Nobody understood my lecture.

2. Event•Music: sonata, symphony, song, performance, concert

   a. Mary couldn't hear the concert.
   b. The rain started during the concert.

Dot Object Inventory: 3

1. Event•Physical: lunch, breakfast, dinner, tea
   a. My lunch lasted too long today.
   b. I pack my lunch on Thursdays.
2. Information•Physical: book, cd, dvd, dictionary, diary, mail, email, mail, letter
   a. Mary burned my book on Darwin.
   b. Mary believes all of Chomsky's books.

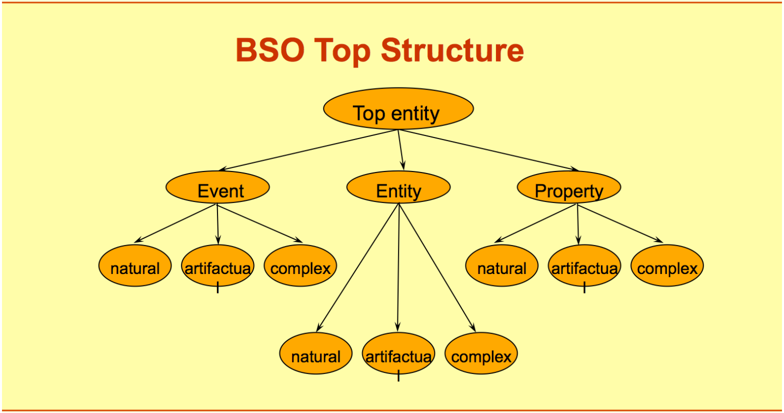
Complex Predicate Types

Predicates formed with a Complex Entity Type as an argument:

1. *read*: $phys \bullet info \rightarrow (e_N \rightarrow t)$
2. Expressed as typed arguments in a λ-expression:
   $\lambda y{:}\, phys \bullet info\ \lambda x{:}\, e_N[read(\mathrm{x,y})]$
3. Mary read the book.

Brandeis Semantic Ontology 1/5

Pustejovsky et al (2006)



Brandeis Semantic Ontology 2/5

- **Qualia** are defined for **Entity** types
- **Argument types** are specified for **Events**
- Type inheritance principles:
  - Inheritance is typed
  - A simple type may inherit its qualia from different supertypes
  - Inheritance for **Entities** follows **qualia** links
  - Inheritance for **Events** mirrors **argument** type inheritance
- Entity hierarchy:
  - **Natural types**
    - Inherit formal quale of supertype
  - **Artifactual types**
    - Inherit telic quale of supertype
    - Formal quale is inherited through **formal mapping**
  - **Complex types**
    - “dot types” (e.g. *building, book, lecture*)
    - very shallow hierarchy
    - inherit from two or three functional and/or natural types

Type Inventory from BSO 3/5

- The type of an argument is a value selected from an inventory of types in the language (Asher and Pustejovsky 2006, Pustejovsky 2011).
- In addition to the Montague types, e and t, GL assumes a richer subtyping over the entity domain than is typically assumed in type theory.
- Among these we find: *human*, *physical_object*, *artifact*, *material*, *substance*, *information*, *location*.

ABSTRACT ENTITY, ANIMATE, ARTIFACT, ATTITUDE, DOCUMENT, DRINK, EMOTION, ENTITY, EVENT, FOOD, HUMAN, HUMAN GROUP, IDEA, INFORMATION, LOCATION, OBLIGATION, ORGANIZATION, PATH, PHYSICAL OBJECT, PROPERTY, PROPOSITION, RULE, SENSATION, SOUND, SUBSTANCE, TIME PERIOD, VEHICLE

Brandeis Semantic Ontology 5/5

Ontology

253 semantic types

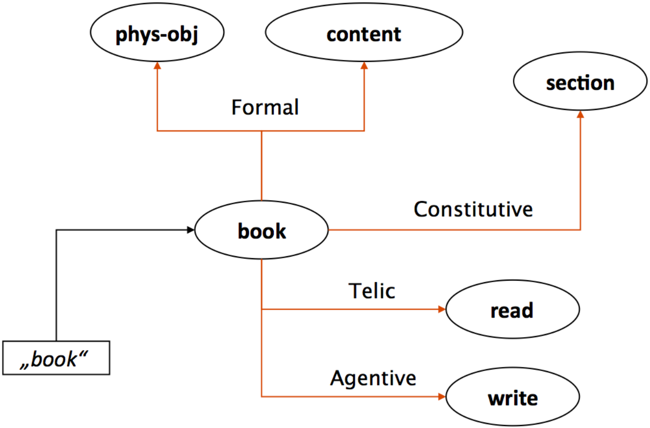
Search Shrink

- Anything details
  - Entity details
    - Abstract_Entity details
      - Concept details
        - Proposition details
          - Narrative details
        - Rule details
          - Permission details
        - Dispute details
        - Information details
      - Information_Source details
        - Document details
          - Agreement details
        - Language details
          - Number details
        - Broadcast details
        - Medium details
        - Radio_Program details
        - Recording details
        - TV_Program details
      - Numerical_Value details
        - Money_Value details
        - Quantity details
      - Psych details
        - Attitude details
        - Emotion details
        - Goal details
      - Resource details
        - Asset details

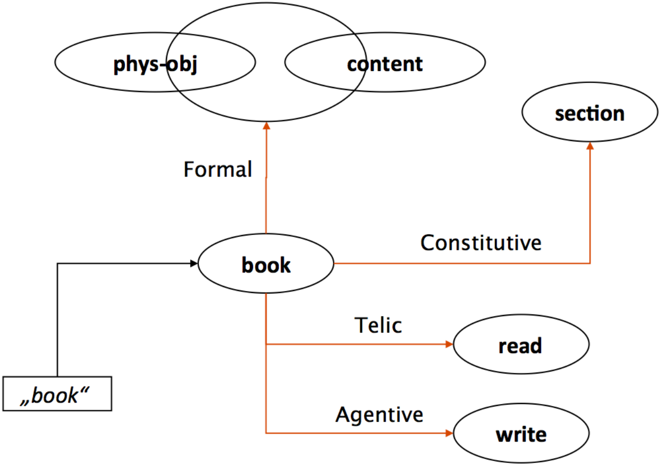
GL and CoreLex

- Lexical semantics Analysis and representation of word meaning
- A generative model of lexical semantics Representation of word meaning that enables dynamic creation of word meanings (√î*senses*√i)*ondemand*
- An empirical foundation of the generative model Analysis of sense distribution across a large-scale semantic lexicon
- An ontological view of lexical semantics Reasoning over the ontology enables sense derivation

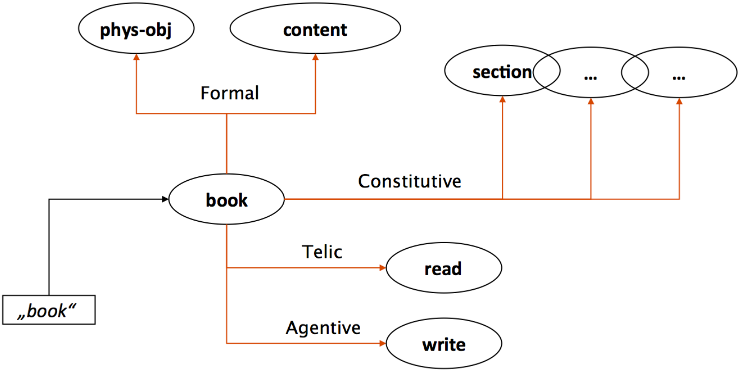
Qualia Structure for book



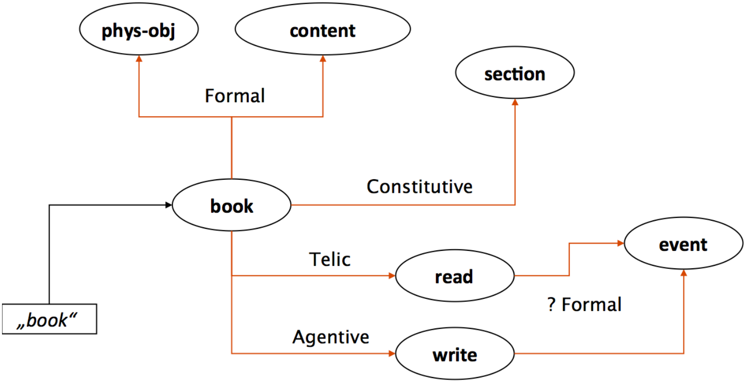
Problems with Formal



Problems with Constitutive



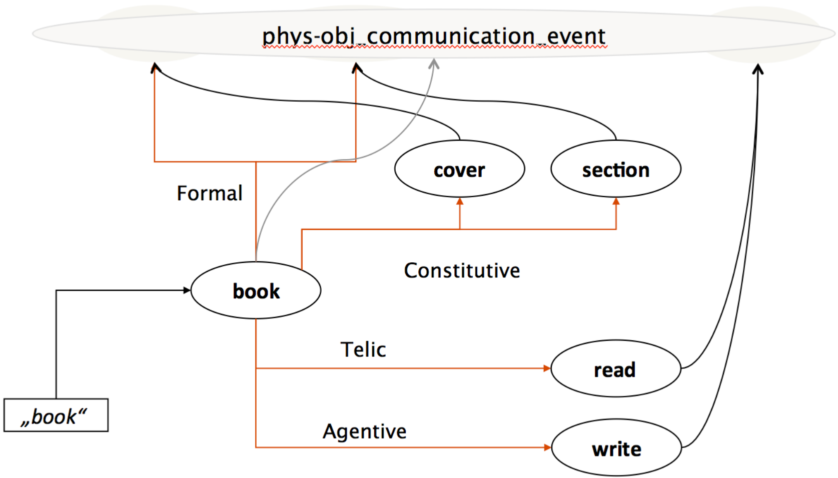
Problems with Telic/Agentive



Two Approaches

- Treat QS as a condensed ontology
  - QS provides a gateway in meaning potential
  - QS roles as shortcuts for ontology inference paths
- Condense QS even further into a complex class
  - Aggregate all types that can be reached through the QS (ontology) into a √î*systematicpolysemousclass*√ï*Eachsystematicpolysemousclassintrod*
  - CoreLex approach (√î*senseclustering*√ï)

QS as Condensed Ontology



Lab on Qualia Identification

- Select one target noun among the following categories (one noun for each category max):
  - Artifactual entities: car, knife, letter, house, table
  - Natural kinds: sea, sun, river, fish, water
  - Functional locations: *library*, *gym*, *church*, *school*.
  - Professions: *doctor*, *teacher*, *lawyer*.
  - Agentive nominals (individuals engaged in an activity, either habitually or occasionally): *passenger*.

Lab on Qualia Identification

- Use the WordSketch function of SkE. Look at full concordances if you need to. Use the patterns if you think they help.
- Identify Qualia Triggers and Qualia Values for the target nouns. Identify Conventional Attributes.
- Compile Qualia structures for the target noun

Qualia Structure for ....

$$\left[\begin{array}{ll} \multicolumn{2}{l}{\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots} \\ \text{QUALIA} = & \left[\begin{array}{lll} \text{F} & = & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \text{C} & = & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \text{T} & = & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \text{A} & = & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \end{array}\right] \end{array}\right]$$

Conventionalized attributes for ....

$$\begin{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \mathrm{QUALIA} = \begin{bmatrix} \mathrm{F} = \begin{bmatrix} \mathrm{F} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \mathrm{CA} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \end{bmatrix} \\ \mathrm{T} = \begin{bmatrix} \mathrm{T} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \mathrm{CA} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Formal-specific Constructions

- [tag="N.*"][lemma="such"][lemma="as"][tag="N.*"]
- [lemma="such"][tag="N.*"][lemma="as"]
- [tag="N.*"][lemma="and"][lemma="other"][tag="N.*"]
- [tag="N.*"][lemma="or"][lemma="other"][tag="N.*"]
- [tag="N.*"][word="including"][tag="N.*"]
- [tag="N.*"][lemma="especially"][tag="N.*"]
- [word="favorite"][tag="N.*"][word="is"][tag="N.*"]

Constitutive-specific constructions

- [tag="N.*"][word="is"][]{0,2}[word="part"][lemma="of"][]{0,2}[tag="N.*"]
- [tag="N.*"][word="made"][lemma="of"][tag="N.*"]
- [tag="N.*"][word="consists"][lemma="of"][]{0,1}[tag="N.*"]
- [tag="N.*"][word="containing"][]{0,2}[tag="N.*"]

Telic-specific constructions

- [lemma="a"][tag="N.*"][word="worth"][tag="VVG"]
- [tag="N.*"][lemma="deserve"|lemma="merit"][tag="VVG"]
- [lemma="enjoy"|lemma="prefer"][tag="VVG"]
- [lemma="a"][tag="N.*"][word="for"][tag="VVG"]
- [lemma="a"][tag="N.*"][word="used"][word="for"] [tag="VVG"]

Agentive-specific constructions

- [tag="N.*"][tag="V.*D"][tag="V.*N|V.*D"]

Aktionsarten – conceptual categories of event types

- Stative vs. Non-stative

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(15) a. John is tall.
b. Mary knows the answer.
c. It is 8:00 p.m.
d. ! John is being tall.

Aktionsarten – conceptual categories of event types

- Stative vs. Non-stative
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Generally only compatible with simple present, but notice extended use of progressive and subtle meaning differences:

Aktionsarten – conceptual categories of event types

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Generally only compatible with simple present, but notice extended use of progressive and subtle meaning differences:

(20) . a. The statue stands in the square.
b. The statue is standing in the square.

Structural vs. Phenomenal distinction – Goldsmith and Woisetschlager (1979)

Temporary vs. permanent states

As seen with the English progressive marking before, states are not always permanent. Other languages also mark these differences (but not always for the same concepts).

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- Spanish – *ser* vs. *estar*

  (22) a. Soy enfermo (I am a sickly person)
  b. Estoy enfermo (if I have a cold)

Processes

- Involve change and are extended in time. In present tense they need to be used in the progressive (unless habitual)

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(25) . a. John ran a mile in under four minutes.
b. Sheila wrote three letters in an hour.
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Processes

- Involve change and are extended in time. In present tense they need to be used in the progressive (unless habitual)

(27) . a. John ran a mile in under four minutes.
b. Sheila wrote three letters in an hour.
c. !John ran a mile for six minutes.
d. !Sheila ate an apple for ten minutes.

(28) a. John ran for twenty minutes.
b. Sheila ate apples for two days straight.
c. !John ran in twenty minutes.
d. !Sheila ate apples in two days.

Distinguishing Processes from Transitions

- Activities: Atelic i.e. have no natural endpoint or goal (e.g. *I'm running in the park*) Compatible with a durative adverbial (e.g. *for*) that profiles the amount of time the activity takes.

Distinguishing Processes from Transitions

- Activities: Atelic i.e. have no natural endpoint or goal (e.g. *I'm running in the park*) Compatible with a durative adverbial (e.g. *for*) that profiles the amount of time the activity takes.
- Accomplishments: Telic i.e. have a natural endpoint of goal (e.g. *I'm running a mile*) Compatible with a container adverbial (e.g. *in*) that profiles the amount of time taken to reach the desired goal.

Typological Effects

Some languages are more systematic than English in distinguishing indicators of actual and potential terminal points. Thus Swedish use different prepositions:

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(31) Jeg reser till Frankrike *på* två månader.
I('m) going to France for two months.

(32) Jeg reste i Frankrike *i* två månader.
I traveled in France for two months.

Achievements and points

Achievements: Events that are conceived of as instantaneous. Often, however, there is an underlying activity that causes a change of state. Their point-like nature tends to require them to be described in the past tense or narrative present.

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(34) a. John shattered the window.
b. ! John shatters/is shattering the window.
c. The canals froze.
d. Mary found her keys.
e. *Mary is finding her keys.
f. John reached the top.

Points: Similar to achievements in being conceived as instantaneous, but without the underlying run-up activity that characterizes gradual achievements

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(36) a. Bill coughed.
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c. Bill is coughing.
d. The light is flashing.

Achievements and points

Points: Similar to achievements in being conceived as instantaneous, but without the underlying run-up activity that characterizes gradual achievements

(37) a. Bill coughed.
 b. The light flashed.
 c. Bill is coughing.
 d. The light is flashing.

(c) and (d) have an iterative interpretation. Compare with the gradual achievements *John is reaching the top* or *The canals are freezing*.

Vendler Event Classes + Semelfactive

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- STATE: John loves his mother.
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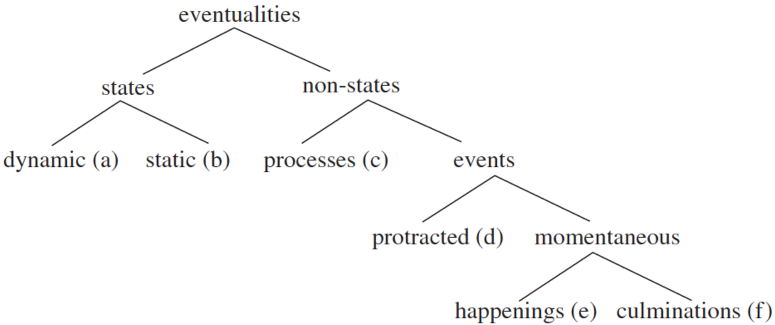
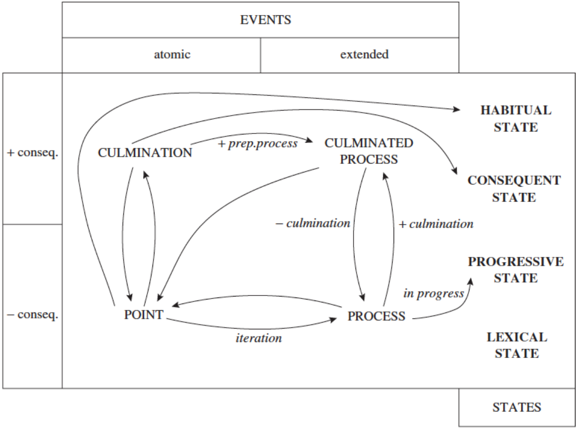
- ACCOMPLISHMENT: Mary wrote a novel.
- ACHIEVEMENT: John found a Euro on the floor.
- POINT: John knocked on the door (for 2 minutes).

Bach Eventuality Typology (Bach, 1986)



Event Transition Graph (Moens and Steedman 1988)



Incremental Theme Verbs

- Certain NP's measure out the event. They are direct objects consumed or created in increments over time (cf. *eat an apple* vs. *push a chart*) (Tenny 1994).

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- In *Mary drank a glass of wine* "every part of the glass of wine being drunk corresponds to a part of the drinking event" (Krifka 1992)
- "Incremental themes are arguments that are completely processed only upon termination of the event, i.e., at its end point" (Dowty 1991).

Degree Achievements

- Verbs with variable aspectual behavior: they seems to be change of state verbs like other achievements , but allow durational adverbs (Dowty 1979, Hay, Kennedy and Levin 1999, Rappaport Hovav 2008).

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- Scalar predicates: verbs which lexically specify a change along a scale inasmuch as they denote an ordered set of values for a property of an event argument (Hay, Kennedy and Levin 1999, Rappaport Hovav 2008).
- For example *cool*, *age*, *lenghten*, *shorten*; *descend*.
- *Let the soup cool for 10 minutes*.
- *I went on working until the soup cooled*.

Points

- Moens and Steedman 1988 analyze point expressions as those that are not normally associated to a consequent state (consequent state defined as no transition to a new state in the world – according to Moens and Steedman a point is an event whose consequences are not at issue in the discourse).

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- Semelfactives (Smith 1990, Rothstein 2004).
- **arrived/landed for five minutes*, *knocked/tapped for five minutes*.
- Points admit iterative readings under coercive contexts (Moens and Steedman 1988).

Aspectual Composition

- Bare plurals and mass-terms arguments can make a sentence with a telic predicate behave as if it were 'durative' or 'imperfective' in aspect (Verkuyl 1972).

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- *John drank beer* (imperfective).

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- *John drank a glass of beer* (perfective).
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Aspectual Coercion

- "A person *leads* somebody somewhere" (PROCESS) vs. "A road *leads* somewhere" (STATE)

Aspectual Coercion

- "A person *leads* somebody somewhere" (PROCESS) vs. "A road *leads* somewhere" (STATE)
- "An object *falls* to the ground" (TRANSITION) vs. "A case *falls* into a certain category" (STATE)

(38) a. EVENT → STATE | PROCESS | TRANSITION

Subatomic Event Structure

Pustejovsky (1991)

(39) a. EVENT → STATE | PROCESS | TRANSITION

b. STATE: → e

(40) a. $\textsc{event} \rightarrow \textsc{state} \mid \textsc{process} \mid \textsc{transition}$
b. $\textsc{state}: \rightarrow \; e$
c. $\textsc{process}: \rightarrow \; e_1 \ldots e_n$

(41)
a. EVENT → STATE | PROCESS | TRANSITION
b. STATE: → e
c. PROCESS: → $e_1 \ldots e_n$
d. TRANSITION$_{ach}$: → STATE STATE

(42)
a. EVENT → STATE | PROCESS | TRANSITION
b. STATE: → e
c. PROCESS: → $e_1 \ldots e_n$
d. TRANSITION$_{ach}$: → STATE STATE
e. TRANSITION$_{acc}$: → PROCESS STATE

Qualia Structure for Causative

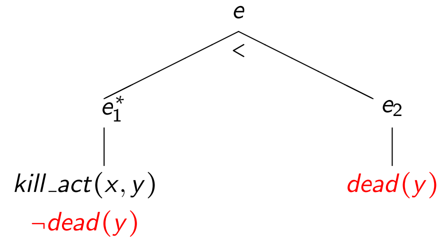
Pustejovsky (1995)

$$
\left[\begin{array}{l}
\textbf{kill} \\
\text{EVENTSTR} = \left[\begin{array}{lll} \text{E}_1 & = & \textbf{e}_1\textbf{:process} \\ \text{E}_2 & = & \textbf{e}_2\textbf{:state} \\ \text{RESTR} & = & <_{\propto} \\ \text{HEAD} & = & \textbf{e}_1 \end{array}\right] \\
\text{ARGSTR} = \left[\begin{array}{lll} \text{ARG1} & = & \boxed{1}\left[\begin{array}{l} \textbf{ind} \\ \text{FORMAL} = \textbf{physobj} \end{array}\right] \\ \text{ARG2} & = & \boxed{2}\left[\begin{array}{l} \textbf{animate\_ind} \\ \text{FORMAL} = \textbf{physobj} \end{array}\right] \end{array}\right] \\
\text{QUALIA} = \left[\begin{array}{l} \textbf{cause-lcp} \\ \text{FORMAL} = \textbf{dead}(\textbf{e}_2, \boxed{2}) \\ \text{AGENTIVE} = \textbf{kill\_act}(\textbf{e}_1, \boxed{1}, \boxed{2}) \end{array}\right]
\end{array}\right]
$$

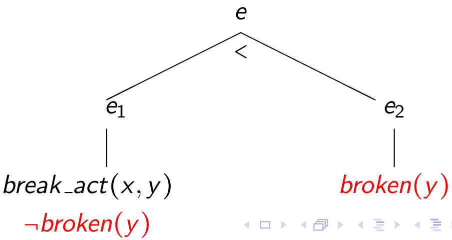
Opposition Structure

Pustejovsky (2000)

(43) kill



(44) break



Qualia Structure with Opposition Structure

$$
\left[\begin{array}{l}
\textbf{kill} \\
\text{EVENTSTR} = \left[\begin{array}{l}
\text{E}_0 = \textbf{e}_0\textbf{:state} \\
\text{E}_1 = \textbf{e}_1\textbf{:process} \\
\text{E}_2 = \textbf{e}_2\textbf{:state} \\
\text{RESTR} = <_\propto \\
\text{HEAD} = \textbf{e}_1
\end{array}\right] \\
\text{ARGSTR} = \left[\begin{array}{l}
\text{ARG1} = \boxed{1}\left[\begin{array}{l}\textbf{ind} \\ \text{FORMAL} = \textbf{physobj}\end{array}\right] \\
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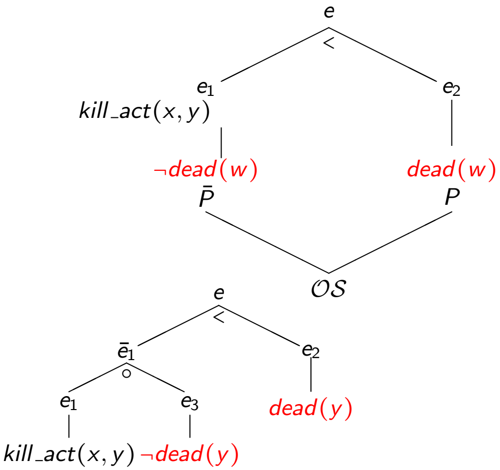
\end{array}\right] \\
\text{QUALIA} = \left[\begin{array}{l}
\textbf{cause-lcp} \\
\text{FORMAL} = \textbf{dead}(\textbf{e}_2, \boxed{2}) \\
\text{AGENTIVE} = \textbf{kill\_act}(\textbf{e}_1, \boxed{1}, \boxed{2}) \\
\text{PRECOND} = \neg\textbf{dead}(\textbf{e}_0, \boxed{2})
\end{array}\right]
\end{array}\right]
$$

Opposition is Part of Event Structure



Dynamic Extensions to GL

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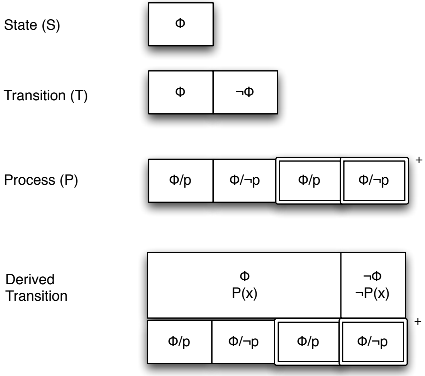
$$\text{Verb}(\text{Arg}_1\text{Arg}_2) \implies \lambda y \lambda x \boxed{P_1(x,y)}_A \boxed{P_2(y)}_F$$

Frame-based Event Structure



2nd Conference on CTF, Pustejovsky (2009)

Dynamic Event Structure

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     $[\alpha]\phi$ (after every execution of α, ϕ is true);
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Dynamic Event Structure

(45) a. Mary was sick today.
b. My phone was expensive.
c. Sam lives in Boston.

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We assume that a *state* is defined as a single frame structure (event), containing a proposition, where the frame is temporally indexed, i.e., $e^i \rightarrow \phi$ is interpreted as ϕ holding as true at time i. The frame-based representation from Pustejovsky and Moszkowicz (2011) can be given as follows:

Dynamic Event Structure

(47) $\boxed{\phi}_e^i$

(50) $\boxed{\phi}^{i}_{e}$

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Semantic interpretations for these are:

(61) a. $[\![\boxed{\phi}]\!]_{\mathbf{M},i} = 1$ iff $V_{\mathbf{M},i}(\phi) = 1$.

b. $[\![\boxed{\phi}\boxed{\phi}]\!]_{\mathbf{M},\langle i,j \rangle} = 1$ iff $V_{\mathbf{M},}(\phi) = 1$ and $V_{\mathbf{M},j}(\phi) = 1$, where $i < j$.

Dynamic Event Structure

(62)

$$\begin{array}{c} e^i \\ | \\ \phi \end{array}$$

Dynamic Event Structure

(63)
$$\begin{array}{c} e^{i} \\ | \\ \phi \end{array}$$

Tree structure for event concatenation:

$$\begin{array}{c} e^{i} \\ | \\ \phi \end{array} \quad + \quad \begin{array}{c} e^{j} \\ | \\ \phi \end{array} \quad = \quad \begin{array}{c} e^{[i,j]} \\ | \\ \phi \end{array}$$

Labeled Transition System (LTS)

The dynamics of actions can be modeled as a Labeled Transition Systems (LTS).

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(71) $(e_1, \alpha, e_2) \in \rightarrow$

cf. Fernando (2001, 2013)

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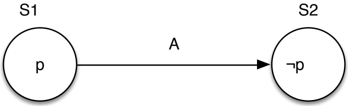

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If reference to the state content (rather than state name) is required for interpretation purposes, then as shorthand for: $(\{\phi\}_{e_1}, \alpha, \{\neg\phi\}_{e_2}) \in \rightarrow$, we use:

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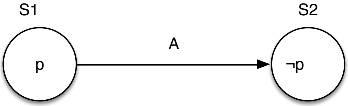

Temporal Labeled Transition System (TLTS)

With temporal indexing from a Linear Temporal Logic, we can define a Temporal Labeled Transition System (TLTS). For a state, e_1, indexed at time i, we say e_1@i.
$(\{\phi\}_{e_1@i}, \alpha, \{\neg\phi\}_{e_2@i+1}) \in \rightarrow_{(i,i+1)}$, we use:

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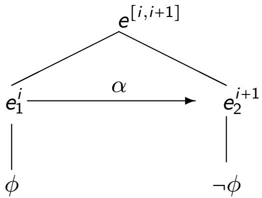
Dynamic Event Structure

(81)



Dynamic Event Structure

(82) Mary awoke from a long sleep.

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The state of being asleep has a duration, $[i, j]$, who's valuation is gated by the waking event at the "next state", $j + 1$.

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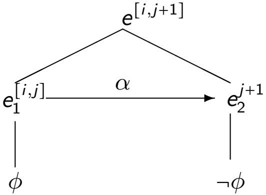

Simple First-order Transition

(88) $x := y$ (ν-transition)
"x assumes the value given to y in the next state."
$\langle \mathcal{M}, (i, i+1), (u, u[x/u(y)]) \rangle \vDash x := y$
iff $\langle \mathcal{M}, i, u \rangle \vDash s_1 \wedge \langle \mathcal{M}, i+1, u[x/u(y)] \rangle \vDash x = y$

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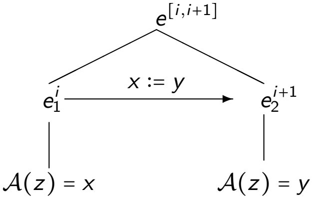
(91)



Processes

With a ν-transition defined, a *process* can be viewed as simply an iteration of basic variable assignments and re-assignments:

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(93)
$$
\begin{array}{c}
e \\
e_1 \xrightarrow{\nu} e_2 \;\ldots\; \xrightarrow{\nu} e_n
\end{array}
$$

Spatial Relations in Motion Predicates

- Topological Path Expressions
  arrive, leave, exit, land, take off

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Language Data

- Manner construction languages
  Path information is encoded in directional PPs and other adjuncts, while verb encode manner of motion

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  Path information is encoded in matrix verb, while adjuncts specify manner of motion
  Modern Greek, Spanish, Japanese, Turkish, Hindi

Defining Motion (Talmy 1985)

(94) a. The *event* or situation involved in the change of location ;

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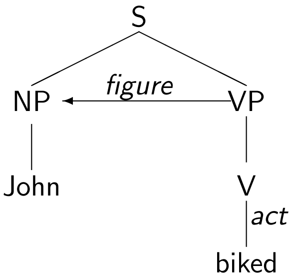
e. The *manner* in which the change of location is carried out;
f. The *medium* through which the motion takes place.

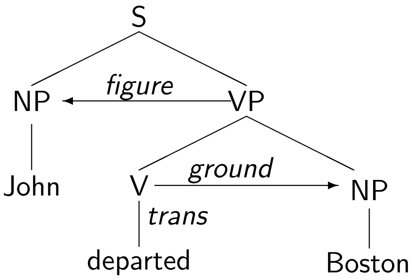
Manner Predicates

(100)



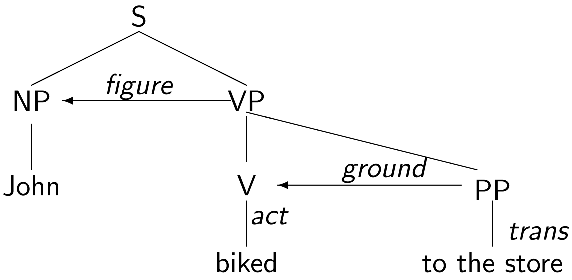
Path Predicates

(101)



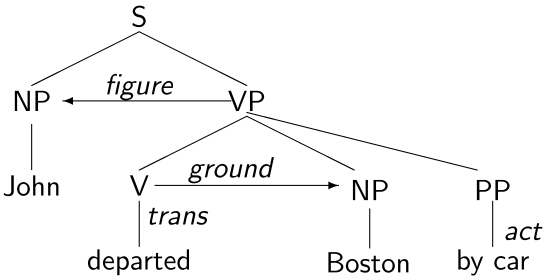
Manner with Path Adjunction

(102)



Path with Manner Adjunction

(103)



Path+manner Predicates (Talmy 2000) 1/2

(104) a. Isabel climbed for 15 minutes.

Path+manner Predicates (Talmy 2000) 1/2

(106) a. Isabel climbed for 15 minutes.
b. Nicholas fell 100 meters.

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(109) a. There is an action (e) bringing about an iterated non-distinguished change of location;

Path+manner Predicates (Talmy 2000) 1/2

(110) a. Isabel climbed for 15 minutes.
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(111) a. There is an action (e) bringing about an iterated non-distinguished change of location;
b. The figure undergoes this non-distinguished change of location;

Path+manner Predicates (Talmy 2000) 1/2

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Path+manner Predicates (Talmy 2000) 1/2

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(116) a. Isabel climbed for 15 minutes.
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c. The figure creates (leaves) a path by virtue of the motion.
d. The action (e) is performed in a certain manner.
e. The path is oriented in an identified or distinguished way.

Path+manner Predicates (Talmy 2000) 2/2

Unlike pure manner verbs, this class of predicates admits of two compositional constructions with adjuncts.

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(120) **Manner of motion verb with path adjunct;**
John climbed to the summit.

Path+manner Predicates (Talmy 2000) 2/2

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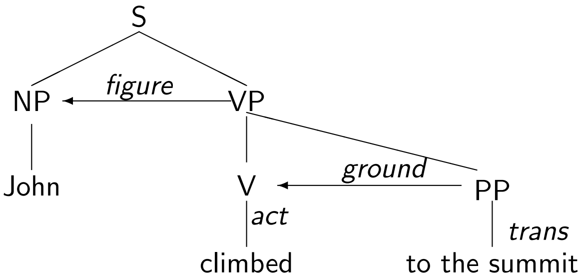
(122) **Manner of motion verb with path adjunct;**
John climbed to the summit.

(123) **Manner of motion verb with path argument;**
John climbed the mountain.

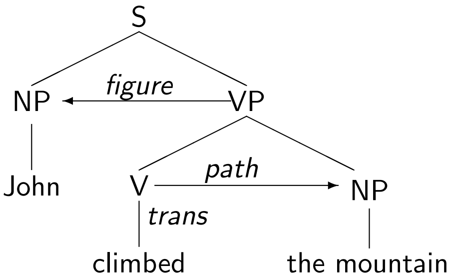
With Path Adjunct

(124)

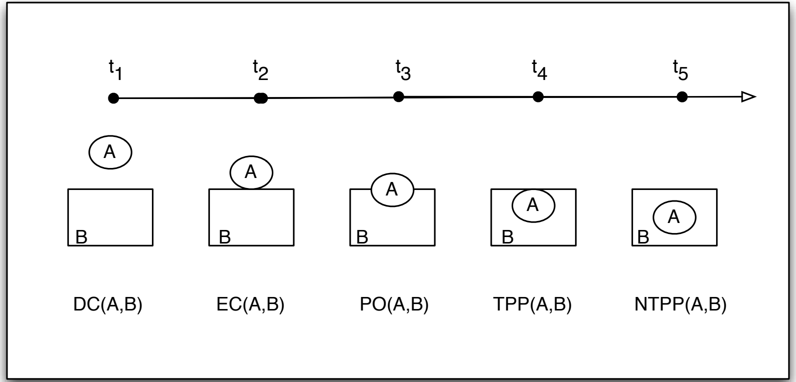


With Path Argument

(125)



Tracking Motion with RCC8: example of enter



Capturing Motion as Change in Spatial Relations

Dynamic Interval Temporal Logic

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- Path verbs designate a distinguished value in the change of location, from one state to another.
  The change in value is tested.
- Manner of motion verbs iterate a change in location from state to state.
  The value is assigned and reassigned.

Directed Motion

(126) $\boxed{loc(z) = x}_{e_1} \xrightarrow{\nu} \boxed{loc(z) = y}_{e_2}$

$x \neq y?$

Directed Motion

(128) $\overset{\overset{x \neq y?}{\curvearrowleft}}{\boxed{loc(z) = x}}_{e_1} \xrightarrow{\nu} \boxed{loc(z) = y}_{e_2}$

When this test references the ordinal values on a scale, $\mathcal{C}$, this becomes a *directed* ν*-transition* ($\vec{\nu}$), e.g., $x \preccurlyeq y$, $x \succcurlyeq y$.

Directed Motion

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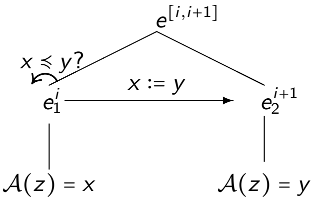
(131) $\vec{\nu} =_{df} \overset{\overset{\mathcal{C}?}{\curvearrowleft}}{e_i} \xrightarrow{\nu} e_{i+1}$

Directed Motion

(132)



Change and Directed Motion

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  $loc(x) := y; y := z$
- Directed motion introduces a dimension that is measured against:
  $d(b, y) < d(b, z)$
- Path verbs introduce a pair of tests:
  $\neg\phi? \ldots \phi?$

Change and the Trail it Leaves

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- For motion, this trail is the created object of the path p which the mover travels on;
- For creation predicates, this trail is the created object brought about by order-preserving transformations as executed in the directed process above.

Motion Leaving a Trail

(133) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$loc(x) := y$

(134) MOTION LEAVING A TRAIL:

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b. Name this value b (this will be the beginning of the movement);

$b := y$

Motion Leaving a Trail

(135) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$$loc(x) := y$$

b. Name this value b (this will be the beginning of the movement);

$$b := y$$

c. Initiate a path p that is a list, starting at b;

$$p := (b)$$

Motion Leaving a Trail

(136) Motion leaving a trail:

a. Assign a value, y, to the location of the moving object, x.

$$loc(x) := y$$

b. Name this value b (this will be the beginning of the movement);

$$b := y$$

c. Initiate a path p that is a list, starting at b;

$$p := (b)$$

d. Then, reassign the value of y to z, where $y \neq z$

$$y := z, y \neq z$$

Motion Leaving a Trail

(137) MOTION LEAVING A TRAIL:

a. Assign a value, y, to the location of the moving object, x.

$loc(x) := y$

b. Name this value b (this will be the beginning of the movement);

$b := y$

c. Initiate a path p that is a list, starting at b;

$p := (b)$

d. Then, reassign the value of y to z, where $y \neq z$

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e. Add the reassigned value of y to path p;

Motion Leaving a Trail

(138) MOTION LEAVING A TRAIL:

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e. Add the reassigned value of y to path p;

$$p := (p, z)$$

f. Kleene iterate steps (d) and (e).

Quantifying the Resulting Trail

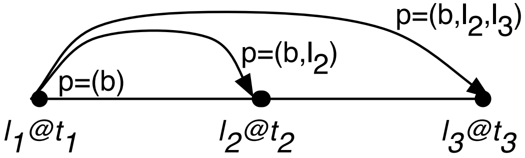

Figure: Directed Motion leaving a Trail

Quantifying the Resulting Trail

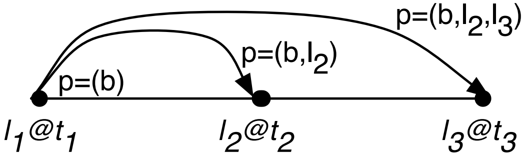

Figure: Directed Motion leaving a Trail

(140) a. The ball rolled 20 feet.
$\exists p \exists x[[roll(x,p) \wedge ball(x) \wedge length(p) = [20, foot]]$

Quantifying the Resulting Trail

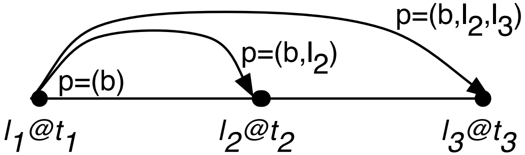

Figure: Directed Motion leaving a Trail

(141) a. The ball rolled 20 feet.

$\exists p \exists x[[\mathit{roll}(x,p) \wedge \mathit{ball}(x) \wedge \mathit{length}(p) = [20, \mathit{foot}]]$

b. John biked for 5 miles.

$\exists p[[\mathit{bike}(j,p) \wedge \mathit{length}(p) = [5, \mathit{mile}]]$

Generalizing the Path Metaphor

- We generalize the Path Metaphor to the analysis of the creation predicates.

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- We analyze creation predicates as predicates referencing two types of scales.

Type of Creation Verbs

(142) a. John wrote a letter.

Type of Creation Verbs

(144) a. John wrote a letter.
b. Sophie wrote for hours.

Type of Creation Verbs

(146) a. John wrote a letter.
b. Sophie wrote for hours.
c. Sophie wrote for an hour.

(147) a. John built a wooden bookcase.
b. *John built for weeks.

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- For example, Rappaport Hovav 2008, Kennedy 2009 claim that "the scale which occurs with incremental theme verbs (extent scale) is not directly encoded in the verb, but rather provided by the referent of the direct object".
- This has lead them to the assumption that when nominal reference plays a role in measuring the change, V is not associated with a scale (denoting a non-scalar change).

Challenge for Scalar Models

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- What is the role of nominal reference in aspectual composition?

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Pustejovsky and Jezek 2012

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- Ratio scales: have equal distances between scale units as well as a zero value. Most measures encountered in daily discourse are based on a ratio scale.

Generalizing the Path Metaphor to Creation Predicates

Pustejovsky and Jezek 2012

- Use multiple scalar domains and the "change as program" metaphor proposed in Dynamic Interval Temporal Logic (DITL, Pustejovsky 2011, Pustejovsky & Moszkowicz 2011).

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- If the program is "change by assignment", Result refers to the record or trail of the change (e.g., the path of a walking, the stuff written in writing, etc.).

Scale shifting

Pustejovsky and Jezek 2012

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- Arguments (selected vs. non-selected, semantic typing, quantification).

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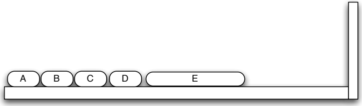
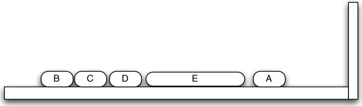
- An ordinal scale drives the incremental creation forward
- A nominal scale acts as a test for completion (telicity)

Incremental Theme and Parallel Scales



- Mary is building a table.
- Change is measured over an **ordinal scale**.
- Trail, τ is null.

Incremental Theme and Parallel Scales



- Mary is building a table.
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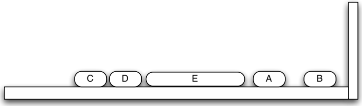
- Trail, $\tau = [A]$.

Incremental Theme and Parallel Scales



- Mary is building a table.
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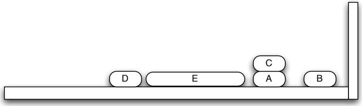
- Trail, $\tau = [A, B]$

Incremental Theme and Parallel Scales



- Mary is building a table.
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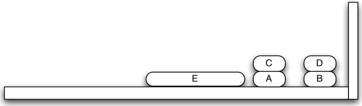
- Trail, $\tau = [A, B, C]$

Incremental Theme and Parallel Scales



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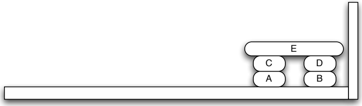
- Trail, $\tau = [A, B, C, D]$

Incremental Theme and Parallel Scales



- Mary built a table.
- Change is measured over a **nominal scale**.
- Trail, $\tau = [A, B, C, D, E]$; $table(\tau)$.

Accomplishments

(148) a. John built a table.

b. Mary walked to the store.

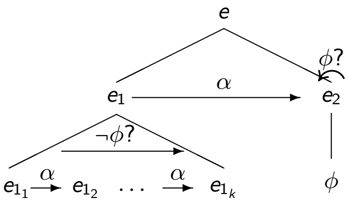
build(x, z, y)	*build*$(x, z, y)^+$	*build*$(x, z, y), y = v$
$\neg$*table*(v)		*table*(v)

$_{\langle i,j \rangle}$

Table: Accomplishment: parallel tracks of changes

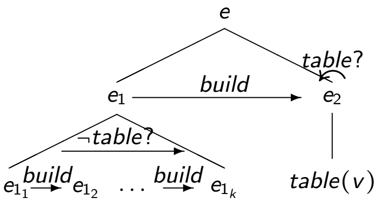
Dynamic Event Structure

(149)



Parallel Scales define an Accomplishment

(150)



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- Arguments saturate (i.e. complete, specify) the meaning of the predicate, and are part of its Qualia, while adjuncts provide supplementary (optional) information.

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- An important feature in GL argument theory is that there is no requirement that for every argument of the relation expressed by a verb there is a corresponding position in the surface syntactic structure containing the verb.
- Arguments may remain unexpressed under certain conditions.

Argument types in GL

- We will consider an inventory of GL argument types which includes four basic types:

Argument types in GL

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- True Arguments.

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- True arguments are **informative** with respect to these properties.

- After she locked the front door, she went to bed.

- After she locked the front door, she went to bed.
- *After she locked, she went to bed.

- After she locked the front door, she went to bed.
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- *I forgot to lock.

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- *Did you lock?

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- *After she locked, she went to bed.
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- *Did you lock?
- *What is she doing? She is locking.

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- John built the house <u>out of bricks</u>.

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- She phoned the office.
- *She phoned the office on the phone.

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- John photographed the whole scene.

Diagnostic for hidden arguments: anaphora

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- Mary translated the Italian poem in two weeks. **It** is a beautiful piece of work.

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- Cathie sliced the bread. We each got **one**.

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$$\begin{bmatrix} \textit{phone.v} & \\ \text{ARGSTR} = & \begin{bmatrix} \text{ARG1} = \textit{human} \\ \text{ARG2} = \textit{human} \\ \text{S-ARG1} = \textit{phone} \end{bmatrix} \end{bmatrix}$$

Thematic Roles and GL

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- Thematic role constraints on arguments, such as *Agent*, *Patient*, *Theme*, *Experiencer*, *Instrument*, etc. are not included in the standard GL argument structure representation.

Thematic Roles and GL

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- Thematic role constraints on arguments, such as *Agent*, *Patient*, *Theme*, *Experiencer*, *Instrument*, etc. are not included in the standard GL argument structure representation.
- The view taken in standard GL is that argument selection is a typing mechanism.
- In Pustejovsky and Jezek 2012, we show how information on participants roles is complementary to typing information and relevant in distinguishing selectional properties of verbs, and may be integrated in the model.

Shadow as Instrument

Shadow as Instrument

- Shadow Instrument is a type of *artifact*.

Shadow as Instrument

- Shadow Instrument is a type of *artifact*.
- bike to the lake shore. (move by S-arg)

Shadow as Instrument

- Shadow Instrument is a type of *artifact*.
- bike to the lake shore. (move by S-arg)

- Shadow Instrument is a type of *substance*.

Shadow as Instrument

- Shadow Instrument is a type of *artifact*.
- bike to the lake shore. (move by S-arg)

- Shadow Instrument is a type of *substance*.
- glue two pieces of wood together. (put together using S-arg)

Shadow as Theme

Shadow as Theme

- Shadow Theme is a type of *artifact*.

Shadow as Theme

- Shadow Theme is a type of *artifact*.
- dress the kids before breakfast. (put S-arg on the kids)

Shadow as Theme

- Shadow Theme is a type of *artifact*.
- dress the kids before breakfast. (put S-arg on the kids)
- Shadow Theme is a type of *substance*

Shadow as Theme

- Shadow Theme is a type of *artifact*.
- dress the kids before breakfast. (put S-arg on the kids)

- Shadow Theme is a type of *substance*
- butter the toast. (put S-arg on toast, cover toast with S-arg)

Shadows as types playing specific roles

$$\begin{bmatrix} \textit{bike.v} \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = \ldots \\ \text{S-ARG}:\textit{instrument} = \textit{bike} \end{bmatrix} \end{bmatrix}$$

Shadows as types playing specific roles

$$\left[\begin{array}{l} \textit{bike.v} \\ \text{ARGSTR} = \left[\begin{array}{l} \text{ARG1} = \ldots \\ \text{S-ARG}:\textit{instrument} = \textit{bike} \end{array}\right] \end{array}\right]$$

$$\left[\begin{array}{l} \textit{butter.v} \\ \text{ARGSTR} = \left[\begin{array}{l} \text{ARG1} = \ldots \\ \text{S-ARG}:\textit{theme} = \textit{butter} \end{array}\right] \end{array}\right]$$

Semantic Type Inventory

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Semantic Type Inventory

- The semantic type of an argument is a value selected from **an inventory of semantic types** in the language.
- In addition to the Montague types, e and t, GL assumes a richer subtyping over the entity domain than is typically assumed in type theory.
- Among these we find: *human*, *physical_object*, *artifact*, *material*, *substance*, *information*, *location*.

Asher and Pustejovsky 2006, Hanks and Pustejovsky 2005, cf. Brandeis Semantic Ontology (BSO).

GL Semantic Types for Composition

GL Semantic Types for Composition

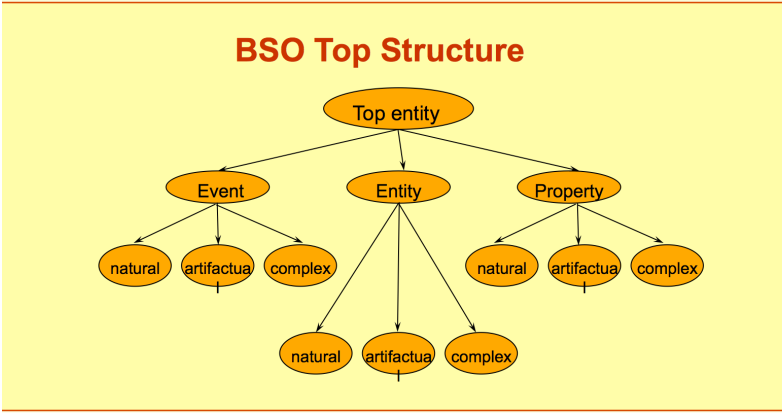
ABSTRACT ENTITY, ANIMATE, ARTIFACT, ATTITUDE, DOCUMENT, DRINK, EMOTION, ENTITY, EVENT, FOOD, HUMAN, HUMAN GROUP, IDEA, INFORMATION, LOCATION, OBLIGATION, ORGANIZATION, PATH, PHYSICAL OBJECT, PROPERTY, PROPOSITION, RULE, SENSATION, SOUND, SUBSTANCE, TIME PERIOD, VEHICLE

Brandeis Semantic Ontology 1/3

Pustejovsky et al (2006)

Brandeis Semantic Ontology 1/3

Pustejovsky et al (2006)



Brandeis Semantic Ontology 2/3

- **Qualia** are defined for **Entity** types
- **Argument types** are specified for **Events**
- Type inheritance principles:
  - Inheritance is typed
  - A simple type may inherit its qualia from different supertypes
  - Inheritance for **Entities** follows **qualia** links
  - Inheritance for **Events** mirrors **argument** type inheritance
- Entity hierarchy:
  - **Natural types**
    - Inherit formal quale of supertype
  - **Artifactual types**
    - Inherit telic quale of supertype
    - Formal quale is inherited through **formal mapping**
  - **Complex types**
    - “dot types” (e.g. *building, book, lecture*)
    - very shallow hierarchy
    - inherit from two or three functional and/or natural types

Brandeis Semantic Ontology 3/3

Ontology 253 semantic types

Search Shrink

- Anything details
  - Entity details
    - Abstract_Entity details
      - Concept details
        - Proposition details
          - Narrative details
        - Rule details
          - Permission details
        - Dispute details
        - Information details
      - Information_Source details
        - Document details
          - Agreement details
        - Language details
          - Number details
        - Broadcast details
        - Medium details
        - Radio_Program details
        - Recording details
        - TV_Program details
      - Numerical_Value details
        - Money_Value details
        - Quantity details
      - Psych details
        - Attitude details
        - Emotion details
        - Goal details
      - Resource details
        - Asset details

GL Types for Composition

(153) a. The spokesman denied the statement (PROPOSITION).

GL Types for Composition

(155) a. The spokesman denied the statement (PROPOSITION).

b. The child threw the stone (PHYSICAL OBJECT).

GL Types for Composition

(157) a. The spokesman denied the statement (PROPOSITION).
b. The child threw the stone (PHYSICAL OBJECT).
c. The audience didn't believe the rumor (PROPOSITION).

(159) a. The spokesman denied the statement (PROPOSITION).

b. The child threw the stone (PHYSICAL OBJECT).

c. The audience didn't believe the rumor (PROPOSITION).

Coercion using Types

GL Types for Composition

(161) a. The spokesman denied the statement (PROPOSITION).
b. The child threw the stone (PHYSICAL OBJECT).
c. The audience didn't believe the rumor (PROPOSITION).

Coercion using Types

(162) a. The president denied the attack (EVENT → PROPOSITION).

GL Types for Composition

(163) a. The spokesman denied the <u>statement</u> (PROPOSITION).
b. The child threw the <u>stone</u> (PHYSICAL OBJECT).
c. The audience didn't believe the <u>rumor</u> (PROPOSITION).

Coercion using Types

(164) a. The president denied the <u>attack</u> (EVENT → PROPOSITION).
b. <u>The White House</u> (LOCATION → HUMAN) denied this statement.

GL Types for Composition

(165) a. The spokesman denied the statement (PROPOSITION).
b. The child threw the stone (PHYSICAL OBJECT).
c. The audience didn't believe the rumor (PROPOSITION).

Coercion using Types

(166) a. The president denied the attack (EVENT → PROPOSITION).
b. The White House (LOCATION → HUMAN) denied this statement.
c. The Boston office called with an update (EVENT → INFO).

Semantic types and co-composition

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The semantic types of the arguments contribute to the assignment of a specific interpretation to the selecting verb in the context of use, i.e. they co-determine verb meaning.

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The semantic types of the arguments contribute to the assignment of a specific interpretation to the selecting verb in the context of use, i.e. they co-determine verb meaning.

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$$\begin{bmatrix} \textit{devour.v} & \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = \textit{human} \\ \text{ARG2} = \textit{document} \end{bmatrix} \end{bmatrix}$$

Semantic Factors and Argument Selection

Pustejovsky and Joshi (2017)

"x PERCEIVE THING BY-MEANS SIGHT"

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1. SIGHT

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1. SIGHT
2. PERCEIVE

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“x PERCEIVE THING BY-MEANS SIGHT”

1. SIGHT
2. PERCEIVE
3. THING

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1. SIGHT
2. PERCEIVE
3. THING
4. BY-MEANS

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1. SIGHT
2. PERCEIVE
3. THING
4. BY-MEANS

Subtypes of See-verbs

Joshi (1972)

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1. *Word sense disambiguation*: the presence of lexical factors influences the likelihood of factor expression in the sentence the lexical item appears in.

Subtypes of See-verbs

Joshi (1972)

- There are 11 basic subtypes, each represented by a unique lexical factorization.
- Within each class, various word senses are distinguished by further factorizations.

1. *Word sense disambiguation*: the presence of lexical factors influences the likelihood of factor expression in the sentence the lexical item appears in.
2. *General factor realization over an entire frame* (semantic expression for a sentence): Independent of a lexical disambiguation decision, it is possible to influence the determination of how to interpret possibly ambiguous (syntactically through attachment or semantically through denotation) adjunct phrases and modifiers.

The verb see

The verb see

The base element of the class, see_0:

The verb see

The base element of the class, *see*$_0$:

- Mary saw a snake.

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The base element of the class, *see*$_0$:

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  BY-MEANS(PERCEIVE(x,THING(y)), SIGHT)

The verb see

The base element of the class, *see*$_0$:

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- Mary saw a snake.
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The verb see

The base element of the class, *see*$_0$:

- Mary saw a snake.
  BY-MEANS(PERCEIVE(x,THING(y)), SIGHT)
- Mary saw a snake crawl into her backpack.
  BY-MEANS(PERCEIVE(x,EVENT(y)), SIGHT)
- Mary saw that John had visited.

The verb see

The base element of the class, *see*$_0$:

- Mary saw a snake.
  BY-MEANS(PERCEIVE(x,THING(y)), SIGHT)
- Mary saw a snake crawl into her backpack.
  BY-MEANS(PERCEIVE(x,EVENT(y)), SIGHT)
- Mary saw that John had visited.
  BY-MEANS(PERCEIVE(x,FACT(y)), SIGHT)

The verb look

The verb look

(170) a. John looked at the tree.

The verb look

(173) a. John looked at the tree.
b. John looked into the cave.

The verb look

(176) a. John looked at the tree.
b. John looked into the cave.
c. John looked towards the tree.

The verb look

(179) a. John looked at the tree.
b. John looked into the cave.
c. John looked towards the tree.

(182) a. John looked at the tree.
b. John looked into the cave.
c. John looked towards the tree.

Subsumes see_0, while wrapping it with an operator, $\textsc{intend}(x, see_0)$:

The verb look

(185) a. John looked at the tree.
b. John looked into the cave.
c. John looked towards the tree.

Subsumes see_0, while wrapping it with an operator, $\text{INTEND}(x, see_0)$:

(186) $\text{INTEND}(\text{x}, \text{BY-MEANS}(\text{PERCEIVE}(\text{x}, \text{THING}(\text{y})), \text{SIGHT}))$

Unlike the **see**-class, however, no eventive or factive reading is possible.

The verb look

(188) a. John looked at the tree.
b. John looked into the cave.
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Subsumes *see*$_0$, while wrapping it with an operator, $\textsc{intend}(x, \mathit{see}_0)$:

(189) $\textsc{intend}(x, \textsc{by-means}(\textsc{perceive}(x, \textsc{thing}(y)), \textsc{sight}))$

Unlike the **see**-class, however, no eventive or factive reading is possible.

(190) a. ?Mary looked at the snake crawl into her backpack.

The verb look

(191) a. John looked at the tree.
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c. John looked towards the tree.

Subsumes see_0, while wrapping it with an operator, $\textsc{intend}(x, see_0)$:

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Unlike the **see**-class, however, no eventive or factive reading is possible.

(193) a. ?Mary looked at the snake crawl into her backpack.
b. ?Mary looked at John's having visited.

The verb glance

The verb glance

This class adds a temporal factor, TEMPORARILY, to the enriched form encoding the **look**-class, where it modifies the duration of the perception act, $\text{INTEND}(x, \text{MOMENTARY}(see_0))$:

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The verb glance

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The verb *glance* has this interpretation as used below.

The verb glance

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(203) a. Mary glanced at the tree.

This class adds a temporal factor, TEMPORARILY, to the enriched form encoding the **look**-class, where it modifies the duration of the perception act, INTEND(x,MOMENTARY(see_0)):

(204) INTEND(x,BY-MEANS(MOMENTARY(PERCEIVE(x,THING(y))), SIGHT))

The verb *glance* has this interpretation as used below.

(205) a. Mary glanced at the tree.
b. John glanced at his watch.

Recall Shadow Arguments

Presupposed but expressible only if it adds new information

(206) a. Harry elbowed me.
b. !Harry elbowed me with his elbow.
c. Harry elbowed me with his arthritic elbow.

(207) a. Mary buttered the bread.
b. !Mary buttered the bread with butter.
c. Mary buttered the bread with creamy, unsalted butter.

Shadow Argument Licensing

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(210) **Shadow Argument Licensing:** A shadow argument, x_s, of type τ, to a verb, v, can be expressed syntactically by a phrase, X, within a sentence, only if the denotation of X is more informative than τ (i.e., it is a subtype or elaboration). Pustejovsky (2000)

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(215) **butter** $=_{df}$
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The semantic factor of BUTTER is incorporated into the verb's meaning, building on a base representation of the relation SPREAD.

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$\lambda z_s : \text{BUTTER} \lambda y : \text{PHYS} \lambda x : \text{HUMAN}[\mathit{spread}(x, y, z)]$

The behavior of the sentences in (207) suggest that lexical factorization can block the syntactic realization of a shadow argument, (207b), unless it is more informative, as in (207c).

Factorization Expression Likelihood 1/3

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- Likewise, if the verb does not incorporate such a factor, it might be more common to see it appear in the syntax.

Factorization Expression Likelihood 2/3

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(225) a. INSTRUMENT: "*with NP*"
Mary saw the star with a telescope.
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Mary looked for the watch in the park.

Factorization Expression Likelihood 2/3

(226) The Factor Expression Thesis: Most semantic components (factors) can be identified with a fixed set of canonical syntactic realization strategies.

(227) a. INSTRUMENT: "*with NP*"
Mary saw the star with a telescope.
b. LOCATION: "*through/in NP*"
Mary looked for the watch in the park.
c. MEDIUM: "*through/in NP*"
The bird flew in the air.

Factorization Expression Likelihood 3/3

Factorization Expression Likelihood 3/3

Some factors encoded in the *see*-class:

Factorization Expression Likelihood 3/3

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(230) a. BY-MEANS: "*by V-ing*"
syn: Mary perceived the star by seeing it.
lex: Mary saw the star.

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lex: Mary saw the star.

b. CAUSE: "*make/cause/let*"

syn: The sun made John unable to see.

lex: The sun blinded him.

Factorization Expression Likelihood 3/3

Some factors encoded in the *see*-class:

(232) a. BY-MEANS: "*by V-ing*"
syn: Mary perceived the star by seeing it.
lex: Mary saw the star.
b. CAUSE: "*make/cause/let*"
syn: The sun made John unable to see.
lex: The sun blinded him.
c. IN-ORDER-TO: "*to VP*", "*in order to VP*"
syn: John looked at the painting closely in order to check its authenticity.
lex: John examined the painting for its authenticity.

Factor Uniqueness

(234) **Factor Uniqueness Hypothesis (version 1)**: Each semantic component (factor) contributing to the meaning of an utterance is *uniquely expressed* in composition. That is, if a factor, f_i, is lexically encoded by a word, w, then it cannot be independently expressed syntactically; and if f_i is expressed syntactically by a phrase, X, it may not be lexically encoded by any word not part of X.

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Given what we have said, however, we have no means of testing whether such a claim is true: namely, without a more formal characterization of the likelihood of a factor being expressed syntactically or not, we cannot measure the dependency between lexical incorporation and syntactic projection.

Defining Factor Expression Likelihood 1/2

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- For all the factors, $\mathbf{f}$, associated with a situational frame, we are interested in the probability of each of these factors, f_i, occurring in an utterance, conditioned on v being selected; i.e., $P(\mathbf{f}|v)$.
- The estimation of the lexical choice for a certain verb, $\hat{v}$, in a particular situation, with given factors, $\mathbf{f}$ as: $\hat{v} = \arg\max_{v \in C} P(\mathbf{f}|v)\, P(v)$.

Defining Factor Expression Likelihood 2/2

Defining Factor Expression Likelihood 2/2

- But this is not entirely correct, since we want to take into consideration the prior probability of all the factors being expressed, independently of the verb, i.e., $P(\mathbf{f})$.
- This we can do by normalizing the conditional, $P(\mathbf{f}|v)$, which is equivalent to $\frac{P(\mathbf{f},v)}{P(v)}$, by $P(\mathbf{f})$, giving us:

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If we focus on each specific factor value, f_i, rather than the random variable, $\mathbf{f}$, then this is, in fact, the well-known concept of *pointwise mutual information*:

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If we focus on each specific factor value, f_i, rather than the random variable, $\mathbf{f}$, then this is, in fact, the well-known concept of *pointwise mutual information*:

(245) $PMI(f_i, v) = log_2 \frac{P(f_i,v)}{P(f_i)P(v)}$

Pointwise Mutual Information

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1. The pointwise mutual information (PMI) compares the probability of a specific factor, f_i, and the verb, v, showing up together (jointly), with the probabilities of seeing f_i and v independently.

Pointwise Mutual Information

(248) $PMI(f_i, v) = log_2 \frac{P(f_i,v)}{P(f_i)P(v)}$

1. The pointwise mutual information (PMI) compares the probability of a specific factor, f_i, and the verb, v, showing up together (jointly), with the probabilities of seeing f_i and v independently.
2. "Word association norms" can be measured in terms of PMI given enough linguistic data, the association between factor expression and lexical choice is also potentially captured with such a metric. (Church and Hanks, 1990)

How Factors Express Syntactically 1/3

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Consider the English verbs *kill* and *murder*.

1. Both these verbs entail an agent causing someone's death, but the latter verb encodes that it is performed intentionally; the factor of INTEND.

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Consider the English verbs *kill* and *murder*.

1. Both these verbs entail an agent causing someone's death, but the latter verb encodes that it is performed intentionally; the factor of INTEND.
2. Assume the canonical syntactic expression for this factor is an adverbial phrase with specific lexicalizations (e.g., *intentionally*, *on purpose*).
3. Then one would expect that this factor would syntactically express for *kill* but not for *murder*.

How Factors Express Syntactically 2/3

[2] We use enTenTen 2012, a corpus of close to 28 million words.

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3. If, on the other hand, there is no relationship of interest between them, then PMI ≈ 0.
4. As intuitively predicted, there appears to be a correlation between the lexical encoding of a factor, f_i, and the absence of any syntactic realization of that factor.

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How Factors Express Syntactically 3/3

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VERB	PMI	ADVERB_SET
kill	6.26	intentionally
-	7.98	accidentally
murder	≈ 0	intentionally
-	≈ 0	accidentally

Table: FEL results

FEL within the see-verbs

FEL within the see-verbs

(250) a. *look*: $\text{INTEND}(x, see_0)$:
John looked at the moon.

FEL within the see-verbs

(251) a. *look*: $\textsc{intend}(x, see_0)$:
John looked at the moon.
b. *glance*: $\textsc{intend}(x,\textsc{momentary}(see_0))$
John glanced at the moon.

FEL within the see-verbs

(252) a. *look*: $\text{INTEND}(x, see_0)$:
John looked at the moon.
b. *glance*: $\text{INTEND}(x, \text{MOMENTARY}(see_0))$
John glanced at the moon.

VERB	PMI	ADVERB_SET
glance	8.5	DIRECTION: sideways, backwards, forwards, downward, skyward
-	6.42	TIME: briefly, again, occasionally, periodically, quickly, swiftly
look	12.22	DIRECTION: forward, backward, ahead, down, straight
-	≈ 0	TIME: briefly, again, occasionally, periodically, quickly, swiftly

Re-analyzing FEL 1/2

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(257) **glance** $=_{df}$

$$\lambda z_s : \text{TIME\_MOMENT} \lambda y : \text{PHYS} \lambda x : \text{HUMAN}[glance(x, y, z)]$$

Re-analyzing FEL 2/2

Re-analyzing FEL 2/2

(259) **Factorization Uniqueness Hypothesis (revised version)**: Each semantic component (factor) contributing to the meaning of an utterance is *uniquely expressed* in composition. That is, if a factor, f_i, is lexically encoded by a word, w, then it cannot be independently expressed syntactically, unless it conveys new information; and if f_i is expressed syntactically by a phrase, X, it may not be lexically encoded by any word not part of X, unless X conveys new information beyond f_i.

Meaning Composition in GL

Meaning composition

- Basic Assumptions
- Simple Function Application
- Coercion
- Data on Argument Typing and Coercion
- Co-composition

GL Type Theory

1. Natural Type: $g \vdash x : \alpha$
2. Artifactual Types:
   1. Artifact Entity: $x : e_N \otimes_a \sigma$
      x exists because of event σ
   2. Functional Entity: $x : e_N \otimes_t \tau$
      the purpose of x is τ
   3. Functional Artifactual Entity: $x : (e_N \otimes_a \sigma) \otimes_t \tau$
      x exists because of event σ for the purpose τ
3. Complex Types: $g \vdash x : \alpha \bullet \beta$

Natural Predicate Types

Predicates formed with Natural Entities as arguments:

1. *fall*: $e_N \rightarrow t$
2. *touch*: $e_N \rightarrow (e_N \rightarrow t)$
3. *be under*: $e_N \rightarrow (e_N \rightarrow t)$

a. $\lambda x{:}e_N[\ \textit{fall}(\mathrm{x})]$

b. $\lambda y{:}e_N \lambda x{:}e_N[\ \textit{touch}(\mathrm{x,y})]$

c. $\lambda y{:}e_N \lambda x{:}e_N[\ \textit{be-under}(\mathrm{x,y})]$

Artifactual Entity Types

Entities formed from the Naturals by adding the AGENTIVE or TELIC qualia roles:

1. Artifact Entity: $x : e_N \otimes_a \sigma$
   x exists because of event σ
2. Functional Entity: $x : e_N \otimes_t \tau$
   the purpose of x is τ
3. Functional Artifactual Entity: $x : (e_N \otimes_a \sigma) \otimes_t \tau$
   x exists because of event σ for the purpose τ

a. *beer*: $(liquid \otimes_a brew) \otimes_t drink$

b. *knife*: $(phys \otimes_a make) \otimes_t cut$

c. *house*: $(phys \otimes_a build) \otimes_t live\_in$

Artifactual Predicate Types

Predicates formed with Artifactual Entities as arguments:

1. *spoil*: $e_N \otimes_t \tau \rightarrow t$
2. *fix*: $e_N \otimes_t \tau \rightarrow (e_N \rightarrow t)$

a. $\lambda x{:}e_A[\ \mathit{spoil}(\mathrm{x})]$

b. $\lambda y{:}e_A \lambda x{:}e_N[\ \mathit{fix}(\mathrm{x,y})]$

- The beer spoiled.
- Mary fixed the watch.

Complex Entity Types

Entities formed from the Naturals and Artifactuals by a product type between the entities, i.e., the dot, $\bullet$.

1. a. Mary doesn't believe the book.
   b. John sold his book to Mary.
2. a. The exam started at noon.
   b. The students could not understand the exam.

Motivating Dot Objects

When a single word or phrase has the ability to appear in selected contexts that are contradictory in type specification.

If a lexical expression, α, where $\sigma \sqcap \tau = \bot$:

1. $[\_\_\_]_{\sigma}$ X
2. $[\_\_\_]_{\tau}$ Y

are both well-formed predications, then α is a dot object (complex type).

Dot Object Inventory: 1

1. Act•Proposition: promise, allegation, lie
   - I doubt John's promise of marriage.
   - John's promise of marriage happened while we were in Prague.
2. Attribute•Value: temperature, weight, height, tension, strength
   - The temperature is rising.
   - The temperature is 23.

Dot Object Inventory: 2

1. Event•Information: lecture, play, seminar, exam, quiz, test
   a. My lecture lasted an hour.
   b. Nobody understood my lecture.
2. Event•Music: sonata, symphony, song, performance, concert
   a. Mary couldn't hear the concert.
   b. The rain started during the concert.

Dot Object Inventory: 3

1. Event•Physical: lunch, breakfast, dinner, tea
   a. My lunch lasted too long today.
   b. I pack my lunch on Thursdays.
2. Information•Physical: book, cd, dvd, dictionary, diary, mail, email, mail, letter
   a. Mary burned my book on Darwin.
   b. Mary believes all of Chomsky's books.

Complex Predicate Types

Predicates formed with a Complex Entity Type as an argument:

1. *read*: $phys \bullet info \rightarrow (e_N \rightarrow t)$
2. Expressed as typed arguments in a λ-expression:
   $\lambda y{:}\, phys \bullet info\ \lambda x{:}\, e_N[read(x,y)]$
3. Mary read the book.

Modes of Composition

(260) a. PURE SELECTION (Type Matching): the type a function requires is directly satisfied by the argument;

b. ACCOMMODATION: the type a function requires is inherited by the argument;

c. TYPE COERCION: the type a function requires is imposed on the argument type. This is accomplished by either:

i. *Exploitation*: taking a part of the argument's type to satisfy the function;

ii. *Introduction*: wrapping the argument with the type required by the function.

Two Kinds of Coercion in Language

- Domain-shifting: The domain of interpretation of the argument is shifted;
- Domain-preserving: The argument is coerced but remains within the general domain of interpretation.

Domain-Shifting Coercion

1. Entity shifts to event:
   I enjoyed the beer
2. Entity shifts to proposition:
   I doubt John.

Domain-Preserving Coercion

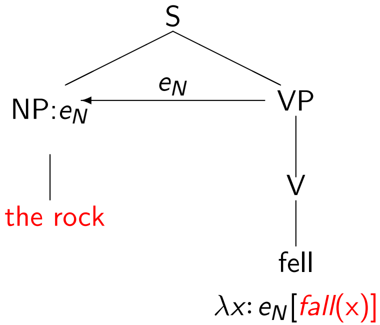
1. Count-mass shifting: There's chicken in the soup.
2. NP Raising: Mary and every child came.
3. Natural-Artifactual shifting: The water spoiled.
4. Natural-Complex shifting: She read a rumor.
5. Complex-Natural shifting: John burnt a book.
6. Artifactual-Natural shifting: She touched the phone.

Direct Argument Selection

- The spokesman denied the statement (PROPOSITION).
- The child threw the ball (PHYSICAL OBJECT).
- The audience didn't believe the rumor (PROPOSITION).

Natural Selection

1. The rock fell.



Natural Selection

(261) a. "fall" is of type *phys* $\rightarrow$ *t*;

b. "the rock" is of type *phys* (modulo GQ type shifting);

c. Function Application (TM) applies;

$\Longrightarrow$ fall(the-rock)

(262) Some water <u>fell</u> on the floor.

This results in the derivation shown in (263):

(263) a. "fall" is of type *phys* $\rightarrow$ *t*;

b. "some water" is of type *liquid* (modulo GQ type shifting);

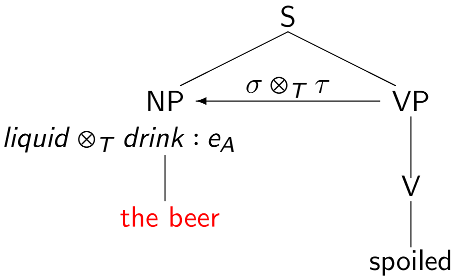
c. Accommodation Subtyping applies, *liquid* $\sqsubseteq$ *phys*:

$\Longrightarrow$ "some water" is of type *phys*:

d. Function Application (TM) applies;

$\Longrightarrow$ fall(some-water)

1. The beer spoiled.



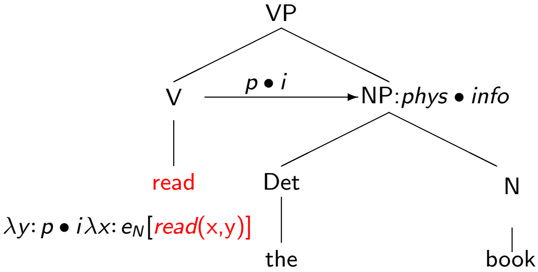
$\lambda x\colon e_A[spoil(x)]$

Pure Selection: Artifactual Type

(264) a. "spoil" is of type $phys \otimes_T \tau \to t$;
b. "the beer" is of type $liquid \otimes_T drink$ (modulo GQ type shifting);
c. Accommodation Subtyping applies to the head, $liquid \sqsubseteq phys$:
$\Longrightarrow$ "the beer" has head type *phys*:
d. Accommodation Subtyping applies to the TELIC, $drink \sqsubseteq \tau$:
$\Longrightarrow$ "the beer" has TELIC type τ
e. "the beer" has type $phys \otimes_T \tau$;
f. Function Application (TM) applies;
$\Longrightarrow$ spoil(the-beer)

Pure Selection: Complex Type

1. John read the book.



Pure Selection: Complex Type

The derivation of this example is fairly direct, and is shown in (265).

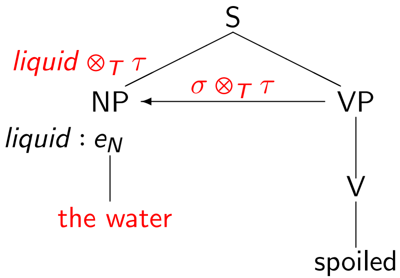
(265) a. "read" is of type $p \bullet i \to (e_N \to t)$;
b. "the book" is of type $p \bullet i$ (modulo GQ type shifting);
c. Function Application (TM) applies;
$\Longrightarrow \lambda x$ [read(x,the-book)]

Coercion of Arguments

- The president denied the attack.
  EVENT → PROPOSITION
- The White House denied this statement.
  LOCATION → HUMAN
- This book explains the theory of relativity.
  PHYS • INFO → human
- d. The Boston office called with an update.
  EVENT → INFO

Type Coercion: Qualia-Introduction

1. The water spoiled.



$\lambda x\colon e_A[\mathit{spoil}(\mathrm{x})]$

Type Coercion: Qualia-Introduction

(266) a. "spoil" is of type $phys \otimes_T \tau \rightarrow t$;

b. "the water" is of type *liquid* (modulo GQ type shifting);

c. Accommodation Subtyping applies to the head,
liquid $\sqsubseteq$ *phys*:

$\Longrightarrow$ "the water" has type *phys*;

d. Coercion by Qualia Introduction (CI-Q) applies to the type *phys*, adding a TELIC value τ:

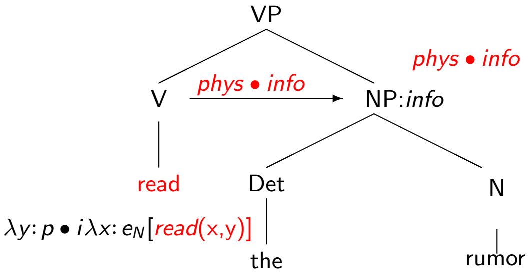
$\Longrightarrow$ "the water" has type $phys \otimes_T \tau$;

e. Function Application applies;

$\Longrightarrow$ spoil(the-water)

Type Coercion: Natural to Complex Introduction

John read the rumor.



Type Coercion: Natural to Complex Introduction

(267) a. "read" is of type $p \bullet i \rightarrow (e_N \rightarrow t)$;

b. "the rumor" is of type i, $i \sqsubseteq t$ (modulo GQ type shifting);

c. Coercion by Dot Introduction (CI-$\bullet$) applies to the type i, adding the missing type value, p, and the relation associated with the $\bullet$:

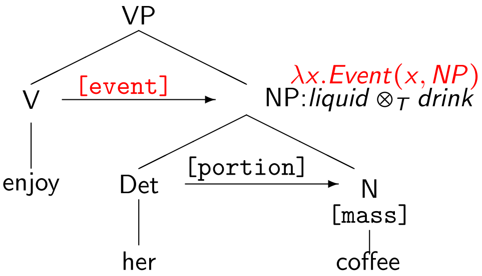
$\Longrightarrow$ "the rumor" has type $p \bullet i$;

e. Function Application applies;

$\Longrightarrow \lambda$x[read(x,the-rumor)]

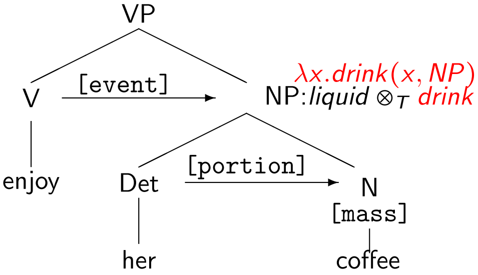
Type Coercion: Event Introduction

1. Mary enjoyed her coffee.



Type Coercion: Qualia Exploitation

1. Mary enjoyed her coffee.



Type Coercion: Qualia Exploitation

(268) a. "enjoy" is of type *event* $\rightarrow (e_N \rightarrow t)$;

b. "her coffee" is of type *liquid* $\otimes_T$ *drink*, (modulo GQ type shifting);

c. Coercion by Introduction (CI) applies to the type *liquid* $\otimes_T$ *drink*, returning *event*:

$\Longrightarrow$ "her coffee" has type *event*;

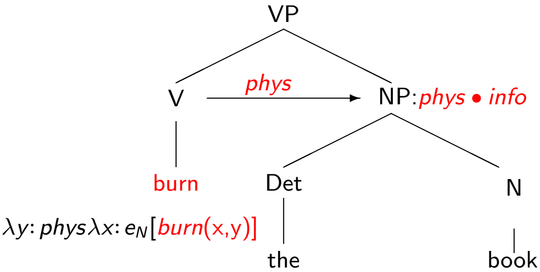
d. Coercion by Qualia Introduction (CI-Q) applies to the type *event*, adding a value *drink* to the predicate, P:

$\Longrightarrow$ "her coffee" has type *event*, with P bound to *drink*;

e. Function Application applies;

$\Longrightarrow \lambda y$[enjoy(y,$\lambda x \exists e$[drink(e,x,her-coffee)]]

1. The police burned the book.
2. Mary believes the book.



Verb-Argument Composition Table

	Verb selects:		
Argument is:	**Natural**	**Artifactual**	**Complex**
Natural	Selection	Qualia Intro	Dot Intro
Artifactual	Qualia Exploit	Selection	Dot Intro
Complex	Dot Exploit	Dot Exploit	Selextion

Data on Argument Typing and Coercion

Pustejovsky and Jezek 2008

- Methodology inspired by Corpus Pattern Analysis (CPA)(Hanks 1994, Pustejovsky et al, 2004, Hanks and Pustejovsky 2005).
- Select a target verb in EnTenTen13 using SkE: *finish*, *last*, *attend*, *avoid*, *drink*, *leave*, *reach*, *smell*, *listen (to)*, *kill*, *ring*.
- Extract a sample of concordances.
- Use CPA list of types.
- Identify typing for specific argument positions in a specific verb sense by manually clustering the argument fillers into lexical sets (Hanks 1996).
- Identify type mismatches.

Data on Argument Typing and Coercion

Pustejovsky and Jezek 2008

(269) *ring* (Body: 'call by phone'; Arg: HUMAN)

Object

a. HUMAN: mother, doctor, Chris, friend, neighbour, director
b. INSTITUTION: police, agency, club
b. LOCATION: flat, house; Moscow, Chicago, London, place

'I rang the house a week later and talked to Mrs Gould'
'The following morning Thompson rang the police'
'McLeish had rung his own flat to collect messages'
'I said Chicago had told me to ring London.'

Data on Coercion: Dot Exploitation

Pustejovsky and Jezek 2008

(270) *house* (PHYS•LOCATION)

Object

a. PHYS: built, buy, sell, rent, own, demolish, renovate, burn down, erect, destroy, paint, inherit, repair

b. LOCATION: leave, enter, occupy, visit, inhabit, reach, approach, evacuate, inspect, abandon

'they built these houses onto the back of the park'

'the bus has passed him as he left the house'

Data on Coercion: Dot Exploitation

Pustejovsky and Jezek 2008

(271) *interview* (EVENT•INFORMATION)

Object

a. EVENT: conduct, give, arrange, attend, carry out, terminate, conclude, close, complete, end, hold, cancel, undertake, extend, control, continue, begin

b. INFORMATION: structure, discuss, analyze, describe

Subject

a. EVENT: last, go well, take place, follow, end, progress, begin, become tedious, precede, start, happen

b. INFORMATION: covers, centre on, concern, focus on

'Officials will be conducting interviews over the next few days'

'Let's discuss the interview'

(272) *hear* (Body: 'perceive with the ear'; Arg:SOUND)
Object

a. SOUND: voice, sound, murmur, bang, thud, whisper, whistle
b. Q-E OF *phys* $\otimes_{telic}\ \tau$: siren, bell, alarm clock

'then from the house I heard the bell'
'you can hear sirens most of the time'
'the next thing he heard was his alarm clock'

Data on Type Introduction

Pustejovsky and Jezek 2008

(273) *read* (PHYS•INFORMATION)

Objects

a. *human* $\otimes_{telic}$ *write*: Dante, Proust, Homer, Shakespeare, Freud

'That is why I read Dante now'

(274) *read* (PHYS•INFORMATION)

Objects

a. EVENT•INFO: story, description, judgement, quote, reply, speech, proclamation, statement, question, interview

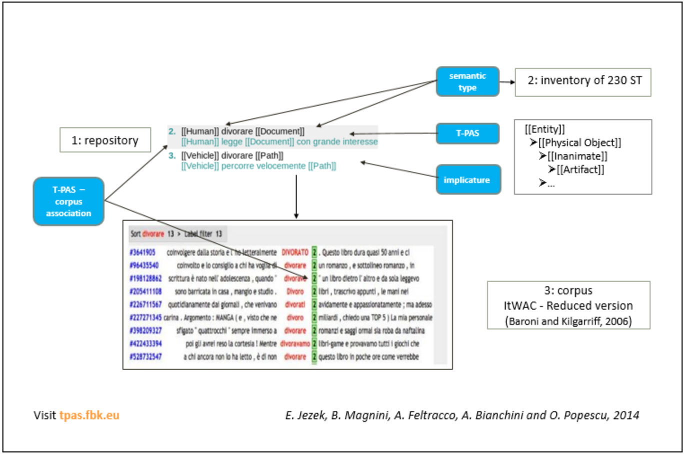
b. SOUND•INFO: music

'I've read your speeches'

'I discovered he couldn't read music'

Typed Predicate-Argument Structure (T-PAS)

Jezek, Magnini, Feltracco, Bianchini, Popescu 2014



Methodology from Hanks, 2004, 2013.

Mismatch classification

- Verb classes (Levin 1993, VerbNet).

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- SemEval Coercion Task 7: Argument Selection and Coercion (Pustejovsky et al. 2010, Jezek and Quochi 2010).

Aspectual Verbs (Jezek, Magnini, Feltracco, Bianchini, Popescu 2014)

[[Human]-subj] interrompe [[Event]-obj]

- Arriva Mirko e interrompe la conversazione.
  'Mirko arrives and interrupts the conversation' (matching)
- Il presidente interrompe l'oratore.
  'The president interrupts the speaker' (HUMAN as EVENT; T=parlare 'speak')

Communication Verbs

[[Human]-subj] annuncia [[Event]-obj]

- Lo speaker annuncia la partenza.
  'The speaker announces the departure' (matching)

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- L'altoparlante annunciava l'arrivo del treno.
  'The loudspeaker announces the arrival of the train' (ARTIFACT as HUMAN; T=usare 'use'(human, tool))

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- Una telefonata anonima avvisa la polizia.
  'An anonymous telephone call alerted the police' (EVENT as HUMAN; AG=telefonare 'phone'(human1, human2))

Avoid Verbs

[[Human]-subj] evita [[Event]-obj]

- Abbiamo evitato l'incontro.
  'We avoided the meeting' (matching)
- Meglio evitare i cibi fritti.
  'It is best to avoid fried food' (ARTIFACT as EVENT; T=mangiare 'eat')

Forbid Verbs

[[Human]-subj] vieta [[Event]-obj]

- Nell'Italia di allora la legge vietava l'aborto.
  'At that time in Italy law prohibited abortion' (matching)
- La Francia vieta il velo a scuola.
  'France bans the headscarf in schools' (ARTIFACT as EVENT; T=indossare 'wear')

Verbs of Desire (Bos 2009)

[[Human]-subj] preferire [[Event]-obj]

- Preferisco bere piuttosto che mangiare.
  'I prefer drinking to eating' (matching)
- Preferisco la birra al vino.
  'I prefer beer to wine' (ARTIFACT as EVENT; T=bere 'drink')

Perception Verbs

[[Human]-subj] ascolta [[Sound]-obj]

- Rilassarsi ascoltando il rumore della pioggia.
  ‘Relax while listening to the sound of rain’ (matching)

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- Rilassarsi ascoltando il rumore della pioggia.
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- Ascoltava la radio con la cuffia.
  'He listened to the radio with his earphones' (ARTIFACT as SOUND: T=produrre_suono 'produce_sound')

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  'I stayed for a long while listening to his breath' (EVENT as SOUND; NT=produrre_suono 'produce_sound')

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  'I stayed for a long while listening to his breath' (EVENT as SOUND; NT=produrre_suono 'produce_sound')
- Non ho potuto ascoltare tutti i colleghi
  'I could not listen to all colleagues' (HUMAN as SOUND; CA=parlare 'speak')

[[Human]-subj] raggiunge [[Location]-obj]

- Abbiamo raggiunto l'isola alle 5.
  'We reached the island at 5' (matching)
- Ho raggiunto il semaforo e ho svoltato a destra.
  'I reached the traffic light and turned right' (ARTIFACT as LOCATION; CA= essere_a 'be_at'(location))

Directed Motion Verbs 2/3

[[Human]-subj] arriva (Adv [[Location]])

- Alla fine, ormai col buio, sono arrivata a una radura.
  'Finally in the dark I came upon a clearing.' (matching)
- Gli invitati arrivano al concerto in ritardo.
  'The guests arrived late at the concert' (EVENT as LOCATION; CA=aver luogo_a 'take place_at'(location))

Motion using a Vehicle

[[Flying Vehicle]-subj] atterra ([Adv [Location]])

- Il nostro aereo atterra alle 21.
  'Our plane lands at 9pm' (matching)

Motion using a Vehicle

[[Flying Vehicle]-subj] atterra ([Adv [Location]])

- Il nostro aereo atterra alle 21.
  'Our plane lands at 9pm' (matching)
- Il pilota e' regolarmente atterrato senza problemi.
  'The pilot landed regularly with no problems' (HUMAN as VEHICLE; T=pilotare 'pilot'(human, vehicle))

Motion using a Vehicle

[[Flying Vehicle]-subj] atterra ([Adv [Location]])

- Il nostro aereo atterra alle 21.
  'Our plane lands at 9pm' (matching)
- Il pilota e' regolarmente atterrato senza problemi.
  'The pilot landed regularly with no problems' (HUMAN as VEHICLE; T=pilotare 'pilot'(human, vehicle))
- Tutti i voli civili sono atterrati.
  'All civilian flights landed' (EVENT as VEHICLE; *ArgStr* Exploitation?)

Vehicle Verbs

[[Human]-subj] parcheggiare ([[Vehicle]-obj])

- Luca ha parcheggiato sotto casa.
  'Luca parked near the house' (matching)
- L'ambulanza ha parcheggiato lontano.
  'The ambulance parked far away' (VEHICLE as HUMAN; T=guidare 'drive'(human, vehicle))

Theory Meets Data

Pustejovsky and Rumshisky (2008)

- Theory predicts phenomena generally by generative rules
- Evidence-based analysis often up-ends the theoretical predictions
- Argument Preferences and Type Selection

Verbs Selecting for Artifactual Entities

(275) a. Natural Verbs: touch, sleep, smile
b. Artifactual Verbs: fix, repair, break, mend, spoil

(276) $\begin{bmatrix} \textbf{touch} \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = x : \mathit{phys} \\ \text{ARG2} = y : \mathit{phys} \end{bmatrix} \end{bmatrix}$

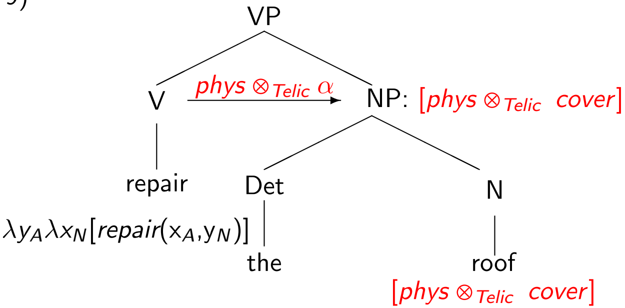
(277) $\begin{bmatrix} \textbf{repair} \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = x : \mathit{human} \\ \text{ARG2} = y : \mathit{phys} \otimes_{\mathit{Telic}} \alpha \end{bmatrix} \end{bmatrix}$

Examples of *repair*-verbs

(278) a. Mary repaired the roof.
b. John fixed the computer.
c. The plumber fixed the sink.
d. The man mended the fence.

Composition with *repair* and NP Object

(279)



Direct object complements for the *repair*-verbs

repair.v			fix.v			mend.v		
damage	107	42.66	pipe	9	11.83	fence	23	32.78
roof	16	20.27	gutter	4	11.45	shoe	10	19.01
fence	10	18.07	heating	5	9.66	puncture	4	18.91
gutter	5	15.87	car	19	9.43	clothes	11	18.68
ravages	4	15.76	alarm	5	9.13	net	8	18.01
hernia	4	15.61	bike	5	9.11	roof	8	16.99
car	23	15.39	problem	23	8.77	car	14	15.45
shoe	10	15.22	leak	3	8.58	way	20	14.26
leak	5	14.96	light	12	8.49	air-conditioning	2	12.71
building	17	14.02	boiler	3	7.96	damage	6	12.71
crack	6	13.99	roof	5	7.27	hole	5	11.38
wall	14	13.77	motorbike	2	7.19	bridge	4	9.68
fault	7	13.56	fault	4	6.91	heart	5	9.6
puncture	3	13.53	jeep	2	6.79	clock	3	9.45
pipe	7	12.89	door	11	6.65	chair	4	9.36
bridge	8	12.19	chain	4	5.48	wall	5	9.27
road	13	12.19	bulb	2	5.15	chain	3	8.3

Selectional Behavior of *repair*-Verbs

(280) *fix.v*

object

a. ARTIFACTUAL: pipe, car, alarm, bike, roof, boiler, lock, engine; heart; light, door, bulb

b. NEGATIVE STATE (condition on the artifact): leak, drip

c. NEGATIVE STATE (general situation): problem, fault

(281) *repair.v*

object

a. ARTIFACTUAL: roof, fence, gutter, car, shoe, fencing, building, wall, pipe, bridge, road; hernia, ligament

b. NEGATIVE STATE (condition on the artifact): damage, ravages, leak, crack, puncture, defect, fracture, pothole, injury

c. NEGATIVE STATE (general situation): rift, problem, fault

(282) *mend.v*

object

a. ARTIFACTUAL: fence, shoe, clothes, roof, car, air-conditioning, bridge clock, chair, wall, stocking, chain, boat, road, pipe

b. ARTIFACTUAL (extended or metaphoric uses): matter, situation; relationship, marriage, relations

c. NEGATIVE STATE (condition on the artifact): puncture, damage, hole, tear

Corpus Evidence Suggests a Different Typing Structure

The verbs select for a negative state of an artifactual type.

(283) a. GENERAL NEGATIVE SITUATION: "fix the problem"
b. CONDITIONS OF THE ARTIFACT: "hole in the wall", "dent in the car".

When the negative relational state is realized, it can either take an artifactual as its object, or leave it implicitly assumed:

(284) a. *repair the puncture / leak*
b. *repair the puncture in the hose / leak in the faucet*

When the artifactual is realized, the negative state is left implicit by default.

(285) a. *repair the hose / faucet*
b. *repair the (puncture in) the hose / (leak in) the faucet*

Revised Typing for *repair*-Verbs

- Selectional properties for the verb *repair* need modification to reflect behavior witnessed from organic data;
- This can be accomplished by positing the negative state as the selected argument of a verb such as *repair*, and the artifactual posited as a *default argument*.

$$(286)\quad \begin{bmatrix} \textbf{repair} \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = x : \mathit{human} \\ \text{ARG2} = y : \mathit{neg\_state}(z) \\ \text{D-ARG1} = z : \mathit{phys} \otimes_{\mathit{Telic}} \alpha \end{bmatrix} \end{bmatrix}$$

Co-compositionality

Pustejovsky (1995, 2013)

- A semantic property of a linguistic expression in which all constituents contribute functionally to the meaning of the entire expression.
- A characterization of how a system constructs the meaning from component parts.
- It is the set of computations within a specific system that should be characterized as co-compositional for those expressions.

Co-compositionality

(287) a. John ran.
b. John ran for twenty minutes.
c. John ran two miles.

(288) a. John ran to the store.
b. John ran the race.

There are two senses of *run* that emerge in context with these examples:

(289) a. run_1: manner-of-motion activity, as used in (287);
b. run_2: change-of-location transition, as used in (288);

Co-compositionality

(290) a. Mary *waxed* the car.
b. Mary *waxed* the car clean.

(291) a. John *wiped* the counter.
b. John *wiped* the counter dry.

(292) a. John *baked* the potato.
b. John *baked* the cake.

(293) a. Mary *fried* an egg.
b. Mary *fried* an omelette.

(294) a. John *carved* the stick.
b. John *carved* a statue.

Co-compositionality

- Informally, we can view co-compositionality as the introduction of new information to an expression by the argument, beyond what it contributes as an argument to the function within the phrase.
- Hence, it can be considered an ampliative operation, relative to the function application.

The Case of bake

(295) $\lambda y \lambda x \lambda e \begin{bmatrix} \textbf{bake} \\ \text{AS} = \begin{bmatrix} \text{A1} = x : \mathit{phys} \\ \text{A2} = y : \mathit{phys} \end{bmatrix} \\ \text{ES} = \begin{bmatrix} \text{E1} = e : \mathit{process} \end{bmatrix} \\ \text{QS} = \begin{bmatrix} \text{A} = \mathit{bake}(e, x, y) \end{bmatrix} \end{bmatrix}$

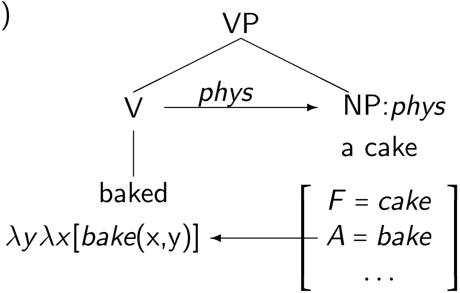
(296)

$$\lambda x \exists y \begin{bmatrix} \textbf{cake} \\ \text{AS} = \begin{bmatrix} \text{ARG1} = x : \mathit{phys} \\ \text{D-ARG1} = y : \mathit{mass} \end{bmatrix} \text{QS} = \begin{bmatrix} \text{F} = \mathit{cake}(x) \\ \text{C} = \mathit{made\_of}(x, y) \\ \text{T} = \lambda z, e[\mathit{eat}(e, z, x)] \\ \text{A} = \exists w, e[\mathit{bake}(e, w, y)] \end{bmatrix} \end{bmatrix}$$

The Agentive for *cake* makes reference to the process within which it is embedded in the sentence (i.e., *bake a cake*), which is a case of cospecification.

- The direct object cospecifies the verb selecting it, since its type structure makes reference to the governing verb, *bake*.

(297)



Co-compositionality

From the underlying *change-of-state* sense of *bake*, the *creation* sense emerges when combined with the NP *a cake*.

$$\exists e_1, e_2, x, y[bake(e_1, j, y) \wedge cake(e_2, x) \wedge made\_of(x, y) \wedge e_1 \leq e_2]$$

The operation of co-composition results in a qualia structure for the VP that reflects aspects of both constituents. These include:

(A) The governing verb *bake* applies to its complement;

(B) The complement co-specifies the verb;

(C) The composition of qualia structures results in a derived sense of the verb, where the verbal and complement AGENTIVE roles match, and the complement FORMAL quale becomes the FORMAL role for the entire VP.

Co-compositionality

The derived sense is computed from an operation called *qualia unification*, introduced in Pustejovsky (1995). The conditions under which this operation can apply are stated in (298) below:

(298) FUNCTION APPLICATION WITH QUALIA UNIFICATION: For two expressions, α, of type `<a,b>`, and β, of type `a`, with qualia structures QS_α and QS_β, respectively, then, if there is a quale value shared by α and β, $[_{QS_\alpha} \ldots [Q_i = \gamma\ ]]$ and $[_{QS_\beta} \ldots [Q_i = \gamma\ ]]$, then we can define the qualia unification of QS_α and QS_β, $QS_\alpha \sqcap QS_\beta$, as the unique greatest lower bound of these two qualia structures. Further, $\alpha(\beta)$ is of type `b` with $QS_{\alpha(\beta)} = QS_\alpha \sqcap QS_\beta$.

The composition in (297) can be illustrated schematically in (299) below.

(299) $\begin{bmatrix}\text{V} & A = \textit{bake}\end{bmatrix} \sqcap \begin{bmatrix}\text{NP} & \begin{matrix} F = \textit{cake} \\ A = \textit{bake}\end{matrix}\end{bmatrix} = \begin{bmatrix}\text{VP} & \begin{matrix} F = \textit{cake} \\ A = \textit{bake}\end{matrix}\end{bmatrix}$

Properties of Co-compositional Derivations

- Within an expression, α, consisting of two subexpressions, α_1 and α_2, i.e., $[_\alpha\ \alpha_1\ \alpha_2]$, one of the subexpressions is an *anchor* that acts as the primary functor;
- Within the argument expression, there is explicit reference to the anchor or the anchor's type (that is, the complement co-specifies the functor);
- The composition of lexical structures results in a derived sense of the functor, within α.

General Co-compositionality

- The derivation for an expression α, is *co-compositional* with respective to its constituent elements, α_1 and α_2, if and only if one of α_1 or α_2 applies to the other, $\alpha_i(\alpha_j)$, $i \neq j$, and $\beta_j(\alpha_i)$, for some type structure β_j within the type of α_j, i.e., $\beta_j \sqsubseteq \mathit{type}(\alpha_j)$.
- $[\![\alpha]\!] = \alpha_i(\alpha_j) \sqcap \beta_j(\alpha_i)$.

The more general characterization of co-compositionality allows us to analyze a number of constructions as co-compositional: *subject-induced coercion* and certain light verb constructions, e.g., *functionally dependent verbs*.

(300) a. The storm killed the deer.

b. An angry rioter killed a policeman.

(301) a. The glass touched the painting.

b. The curious child touched the painting.

(302) a. The ball rolled down the hill.

b. John rolled down the hill as fast as he could.

(303) a. The room cooled off quickly.

b. John cooled off with an iced latte.

Induced Agency

- Let us characterized “agency”, in terms of Qualia Structure, as referring to the potential to act towards a goal.
- For a cognitive agent, such as a *human*, this amounts to associating a set of particular activities, $\mathcal{A}$, as the value of the Agentive role, and
- A set of goals, $\mathcal{G}$, associated with the Telic role in the Qualia for that concept.

(304) $\lambda x \begin{bmatrix} \textbf{human\_agent} & \\ \text{QS} = \begin{bmatrix} \text{F} = \textit{human}(x) \\ \text{T} = \lambda e'[\mathcal{G}(\mathbf{e',x})] \\ \text{A} = \lambda e[\mathcal{A}(\mathbf{e,x})] \end{bmatrix} \end{bmatrix}$

Induced Agency

$$(305)\quad \lambda y \lambda x \lambda e_2 \lambda e_1 \begin{bmatrix} \textbf{kill} & \\ \text{AS} = \begin{bmatrix} \text{A1} = x : \mathit{phys} \\ \text{A2} = y : \mathit{phys} \end{bmatrix} & \text{ES} = \begin{bmatrix} \text{E1} = e_1 : \mathit{process} \\ \text{E2} = e_2 : \mathit{state} \end{bmatrix} \\ \text{QS} = \begin{bmatrix} \text{F} = \mathit{dead}(e_2, y) \\ \text{A} = \mathit{kill\_act}(e, x, y) \end{bmatrix} & \end{bmatrix}$$

(306) a. The door opened.
b. Mary opened the door.

(307)
$$\left[\begin{array}{l}\textbf{open}\\ \mathrm{AS} = \left[\begin{array}{lll}\mathrm{A1} & = & x : \mathit{anim}\\ \mathrm{A2} & = & y : \mathit{phys}\end{array}\right]\\ \mathrm{ES} = \left[\begin{array}{lll}\mathrm{E1} & = & e_1 : \mathit{state}\\ \mathrm{E2} & = & e_2 : \mathit{state}\\ \mathrm{E3} & = & e_3 : \mathit{process}\end{array}\right]\\ \mathrm{QS} = \left[\begin{array}{lll}\mathrm{F} & = & \mathit{open}(e_2, y)\\ \mathrm{A} & = & \mathit{act}(e_3, x, y) \wedge \neg \mathit{open}(e_1, y)\end{array}\right]\end{array}\right]$$

(308) a. Mary opened the book.
b. They opened the trail.
c. Mary opened the door.
d. Bill opened Microsoft Word.

(309)
$$\left[\begin{array}{l} \textbf{open} \\ \text{AS} = \left[\begin{array}{l} \text{A1} = x:\textbf{anim} \\ \text{A2} = y:\textbf{phys}\ [\text{TELIC} = \alpha] \end{array}\right] \\ \text{ES} = \left[\begin{array}{l} \text{E1} = e_1:\textbf{state} \\ \text{E2} = e_2:\textbf{state} \\ \text{E3} = e_3:\textbf{process} \end{array}\right] \\ \text{QS} = \left[\begin{array}{l} \text{F} = \alpha(e_2, y) \\ \text{A} = act(e_3, x, y) \wedge \neg\alpha(e_1, y) \end{array}\right] \end{array}\right]$$