

From Natural Logic to Grounded Language

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Outline

- Natural logic
How it sheds light on implicative predicates
- Natural logic and NLP: ‘Textual Entailment’
- Beyond Natural Logic: grounding in the world (case study: spatiotemporal language)
- Beyond Natural Logic: grounding in speaker expectations (case study: evaluative adjectives)

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Natural Logic

- Natural Logic: proof theoretical logic taking natural language as its formal representation
- *Latin as a formal language*
Omnes homines mortales sunt. All men are mortal. (MaP)
Omnes Graeci homines sunt. All Greeks are men. (SaM)
 \therefore Omnes Graeci mortales sunt. All Greeks are mortal. (SaP)
- A subset of Latin was used as the formal language but the aim was to construct deductions, not a model theoretical interpretation.
- Natural Logic: monotonicity calculus based on NL Representation.

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Importance of the syntactic representation

- In Natural Logic Monotonicity is read off of a highly structured Natural Language representation
- van Benthem, Sánchez Valencia, Dowty, Van Eijck: Categorical Grammar representations.
- MacCartney: context-free phrase structure representation
- Leibniz and De Morgan got the *tail of the horse* wrong because they didn’t have the right *syntactic analysis*. If you reason on strings it is difficult to get it right. (Medieval suppositio theory)

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Extensions of Natural Logic

- MacCartney: *inclusion* and *exclusion* relations that are an extension of the monotonicity calculus.
- Formalized by Thomas Icard III.

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Beyond monotonicity: MacCartney’s inclusion and exclusion relations

symbol	name	example	definition
$x = y$	equivalence	couch = sofa	$x = y$
$x \sqsubset y$	forward entailment	crow \sqsubset bird	$x \sqsubset y$
$x \supset y$	reverse entailment	European \supset French	$x \supset y$
$x \wedge y$	negation	human \wedge nonhuman	$x \cap y = \emptyset \wedge x \cup y = U$
$x y$	alternation	cat dog	$x \cap y = \emptyset \wedge x \cup y \neq U$
$x \cup y$	cover	animal \cup nonhuman	$x \cap y \neq \emptyset \wedge x \cup y = U$
$x \# y$	independence	hungry # hippo	(all other cases)

New: (negation), alternation, cover

MacCartney and Manning 2009

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Semantics of complementation

Kim said that she had scheduled a meeting.
no commitment to the truth of the *complement clause*

Kim remembered **that** she had scheduled a meeting.
 Kim **didn't** remember **that** she had scheduled a meeting.
presupposes that Kim had scheduled a meeting (**factive** construction)

Kim remembered **to** schedule a meeting.
entails that Kim scheduled a meeting (**implicative** construction)
 Kim **didn't** remember **to** schedule a meeting.
entails that Kim did no schedule a meeting (**implicative** construction)

Implicative constructions

Implicative constructions yield an entailment about the truth or falsity of their complement clause.

Some are simple verbs like **forget to** and **remember to**, some are phrasal construction like **take the trouble to**.

There are six different kinds of implicative constructions. Each of them has one the six possible implicative signatures:

+/- **-/+** **+/0** **-/0** **0/-** **0/+**

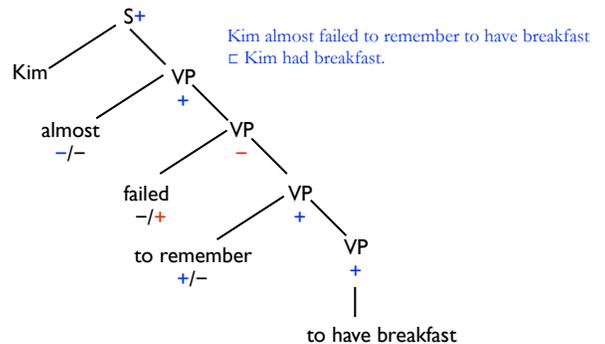
depending on whether the construction has a positive, a negative or no entailment when it occurs in a **positive** or a **negative** environment.

Two-way implicatives

remember to X	+/-	forget to X	-/+
+ Kim remembered to X		+ Kim forgot to X	
entails + Kim Xed		entails - Kim did not X	
- Kim did not remember to X		- Kim did not forget to X	
entails - Kim did not X		entails + Kim did X	

Simple entailments
 And a conventional implicature that that Kim intended to or was expected to X.

Example of a chain of implicatives



First implemented in Nairn, Condoravdi and Karttunen

One-way implicatives

Mary was not able to leave. **0/-**
entails Mary did not leave.

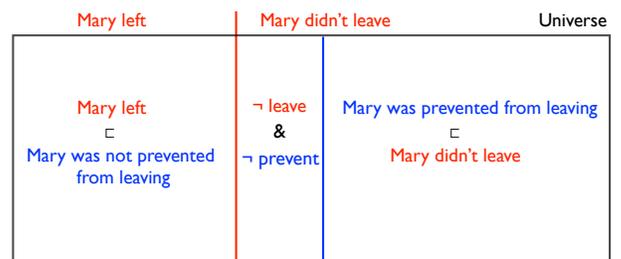
Mary was able to leave.
no commitment (but often meant that she left)

Kim prevented Mary from leaving. **-/0**
entails Mary did not leave.

Kim did not prevent Mary from leaving.
no commitment (but often meant that she left)

One way implicatives: -/0

Mary was prevented from leaving
 Mary was not prevented from leaving
 The join of negation and cover is entailment: $\wedge \exists \cup = \sqsubset$
Mary was not prevented from leaving \cup **Mary didn't leave**



Mary was not prevented from leaving \cup Mary was prevented from to leaving

$x \cap y \neq \emptyset \wedge x \cup y = U$

Textual Entailment: a more general notion of NatLog?

- Proof theory is attractive for NLP: computers handle syntax, do most of the time not have access to semantics.
- Successful NLP applications tend to relate textual input to textual output.
- PASCAL Textual entailment challenge (See CSLI LiLT publication in the back, also available on line.)

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PASCAL Textual Entailment Challenge

- **Textual?** Commonsensical world knowledge also OK.
- **Entailment?** Not really: plausible inferences are also OK.
- **Proofs?** Some approaches call it that way, all kind of plausibility rewrite rules are OK.
- Logical vocabulary: 'textual entailment', 'proofs' to go from input to output sentence but in fact the PASCAL challenge was not about *entailment* but a much looser inference relation and not strictly *textual* but allowing all kinds of world knowledge representations to be added to the mix. The *proofs* rewrite the sentences but also add any information deemed useful.

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'Real' Textual Entailment?

- Textual Entailment:
 - linguistic form as input and as output
 - proofs are rewrites based on the linguistic form and lexical taxonomies (WordNet)
 - proofs are entailments
- Relation between an Input and an Output *sentence*, but the intermediate representations can use other formalizations
- Partially embodied in the PARC Bridge system
- Entailment and Contradiction calculus decides whether there is an entailment, a contradiction or neither.
- Does monotonicity, implicatives and even factives.

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Promising applications of the NatLog approach: spatio-temporal language

- I left my wallet in the car, The car is in the garage \rightarrow My wallet is in the garage. (monotonicity of *in NP*)
- A is to the right of B \rightarrow B is to the left of A. (negation)

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Promising extensions of the NatLog approach

- John entered the room
 - John was outside of the room at time 1
 - John was inside the room at time 2
 - Time 1 was before time 2
- doesn't follow from NatLog but it isn't beyond the scope of spatial logic: can e.g. be represented in RCC8, combined with temporal logic
- There are computationally manageable versions of temporal and spatial logics e.g. James Allen's temporal calculus & RCC8 spatial calculus.
- Philippe Muller, 1998, presents accounts for French verbs like *leave*, *reach*, *cross*, *enter*.
- Wolter and Zakharyashev, 2002, discuss decidability and tractability of these combinations
- Goes beyond Natural Logic but stays within the spirit.

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The perversity of natural language: Same language, different entailments

- Liz **went** *from Palo Alto to Austin*.
- The road **went** *from Palo Alto to Menlo Park*.
- The meeting **went** *from 4 pm to 6 pm*.
- The **temperature** **went** *from 30 degrees to 50 degrees*.
- The **room** **went** *from 30 to 50 degrees*.
- *From front to back*, the **room** **went** *from 30 to 50 degrees*.
- *From 8 a.m. to 10 a.m.* the temperature **went** *from 10 to 15 degrees C*.

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Beyond **textual** logic to grounding in the world

- It is possible to develop formal representations for each of these different meanings.
- Which *textual elements* distinguish the various interpretations?

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Trying to distinguish extent and movement readings

- **Liz** went *from Palo Alto to Menlo Park*.
- **The road** went *from Palo Alto to Menlo Park*.

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Characterizing the subject NPs

- Subjects for **stative** reading: + spatial extent
Common nouns for geographical/spatial features: tunnel, road, rail road, border, ...
Names of roads: A85, Tinnos Line, ...
but also: common nouns for objects with spatial extension: suppressor, staircase, ...
“... The suppressor, 2 inches in diameter, *went all the way from the back of the barrel to well beyond the muzzle* (the suppressor makes up half the overall length of the rifle), providing a very large volume of space to contain the gases produced by firing.”
- Subjects for **dynamic** readings: + moveable
Person names: Peter IV, Dharendra Bahadur Rasalli, ...
Common nouns for persons or groups: trader, army, ...
but also: Moveable objects: ball, painting, ...
Events: parade, expedition, ...
“The *painting* went from Florence to Rome, then to Paris, then Amsterdam. It was in Amsterdam until World War II, ...”

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A problem for NLP or a more general point?

- Fine-grained typing with take care of this. These types can be read off lexical taxonomies.
- NLP problem: we don't have lexical taxonomies that correspond to the required types.

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How fine-grained?

- Only a problem for NLP? Or also for textual entailment in general?
Eric went *from Stanford to MIT* ~ Eric went *from Harvard to MIT*
“That is a long train! It goes *from one end of the station to the other*.”
“It has to be: it goes every day *from Paris to Istanbul*.”
- The types are not static, they come from contextual interpretation based on world knowledge.
- Attempts to turn the problem into a linguistic one: distributional semantics? dotted types? packed representations?
- Human beings are not doing proof-theoretical rewrites, we are interpreting against a model in the world.

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Is that bad?

- Do we actually do a lot of proof-theoretical spatio-temporal reasoning in daily life?
- Directions rely heavily on landmarks.
- When one composes e.g. the RCC8 relations, one gets pretty soon a very underdetermined outcome.
- Maybe we do not need a strong proof-theoretical component for this kind of thinking as it is embodied in natural language.

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Tentative conclusion

- You can do formal reasoning in natural language without translating it into a formal language, perhaps more than you thought possible, just using the syntactic structure and monotonicity and implicative properties of lexical items.
- The formalization throws light on the behavior of implicatives. There are limits to what language-based proof theory can do.
Need for grounding in models of the world, currently
 - robotics
 - structured databases
- Can grounding reduce the logical complexity of the NL component?

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Beyond Natural Logic: grounding in speaker/hearer based language use

- Evaluative adjectives:

The Raiders were *stupid* to draft Russell.
He was *brave* to show us the false leg.
She was *clever* to hide the knives.
Mary was *brave* to venture out in the dark.
John was *stupid* to waste all his money.
John was *clever* to take the best piece.

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Evaluative adjectives are assumed to be factive:

Sentences of the form *NP was not ADJ to VP* can be understood *factively* implying that NP VPed.

The Raiders were **not** stupid to draft Russell. → the Raiders drafted Russell.
He was **not** brave to show us his false leg. → he showed us his false leg
She was **not** clever to hide the knives. → she hid the knives

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Discourse coherence effects

Consonance/dissonance effect (discourse coherence) between adjective and infinitival complement:

Mary was **not** brave to venture out in the dark. → she did not venture out.
John was **not** stupid to waste all his money. → he did not waste his money.
John was **not** clever to take the best piece. → he did not take the best piece.

Sentences of the form *NP was not ADJ to VP* can be understood *factively* implying that *NP VPed* or *implicatively* meaning that *NP did not VP*. The preferred interpretation is sensitive to the hearer's opinion of whether *VPing* would be *ADJ* or not.

[Wasting money]_{VP} would be stupid_{ADJ}

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Consonance/Dissonance

- Constructions of the form *be ADJ to VP* are CONSONANT if it is generally thought that '*to VP would be ADJ.*' **stupid - waste money**
- If it the prevalent opinion is that '*to VP would not be ADJ.*' we have a DISSONANT construction. **clever - waste money**
- If there is no prevailing view of whether '*VPing would or would not be ADJ.*' the construction is NEUTRAL. **clever - have a cold**

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Consonance/Dissonance Effect

The interpretation of sentences like

John was not **clever** to take the **best** piece. (CONSONANT)

John was not **clever** to take the middle piece. (NEUTRAL)

John was not **clever** to take the **worst** piece. (DISSONANT)

is influenced by the perceived relation between the adjective and the VP.
Negation of a **consonant** relation is biased towards an **implicative** interpretation,
negation of a **dissonant** relation favors the **factive** interpretation.

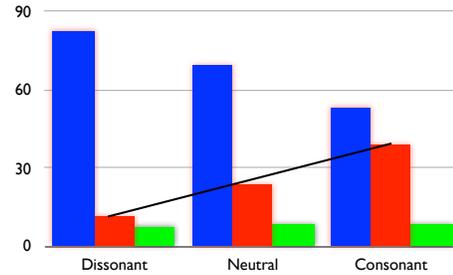
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Consonance/Dissonance Effect

stimulus	adjective - complement relation	answers	Interpretation	%
R. was not clever to choose the best piece.	choosing the best piece is clever CONSONANT	R. chose the best piece.	F	25
		R. did not choose the best piece.	I	64.2
		undecided		10.7
R. was not clever to choose the worst piece.	choosing the worst piece is not clever DISSONANT	R. chose the worst piece.	F	80
		R. did not choose the worst piece.	I	10
		undecided		10
K. was not stupid to save money.	saving money is not stupid DISSONANT	K. saved money.	F	78.6
		K. did not save money.	I	14.2
		undecided		7.1
K. was not stupid to waste money.	wasting money is stupid CONSONANT	K. wasted money.	F	28.6
		K. did not waste money.	I	66.7
		undecided		4.8

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Factive vs. Implicative



NP was not Adj to VP.

Did NP VP?

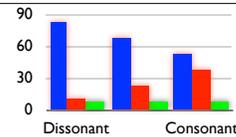
YES NO NEITHER

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Ways to interpret the data

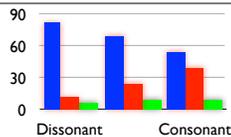
- Mistakes: people think that they hear/write/say/ "enough"
We asked the test subjects who gave an implicative interpretation whether they would express this thought the same way, most said yes.
Mixed data on the web.
Equal number of implicative and factive occurrences in EnTen corpus for e.g. *stupid*.

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- Interpretation of the consonant cases as implicative/ dissonant cases as factive
John was **not** stupid to **waste** money. John was **not** stupid to **save** money
Assumption: It is stupid to **waste** money. Assumption: It is **not** stupid to **save** money.
Assertion: John was **not** stupid. Assertion: John was **not** stupid.
Conclusion: John did not waste money. Conclusion: John saved money.
No accommodation to the presupposition but maintenance of a previous assumption.
Production: ???
Why does it only happen in the negative?

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- Interpretation of the neutral data:
Two dialects? Or maybe what we thought was neutral was not neutral for everybody. Object of an new experiment.
- Interpretation of the dissonant data as implicative: 'noise'
- How do people process sentences that, according to standard linguistic analysis, contradict their assumptions?
- How do people handle negation? Is there anything odd going on with **too** and **enough**, with comparison in general?
<http://languagelog.ldc.upenn.edu/nll/index.phps=misnegation&paged=4>
- Language processing, fast and slow? Cf. Rens Bod and collaborators.

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No WUG is too DAX to be ZONGED (No head injury is too trivial to be ignored)

- Wason and Reich (1979) / Cook and Stevenson (2012)
No head injury is too trivial to be ignored.
No interest is too narrow to deserve its own newsletter.
"correct" "incorrect"
- Pragmatic sentences

1. No missile is too small to be banned.	16	0
2. No government is too secure to be overthrown.	16	0
3. No dictatorship is too benevolent to be condemned.	11	5
4. No weather forecast is too plausible to be mistrusted.	8	8
- Non-pragmatic sentences

5. No error is too gross to be overlooked.	3	13
6. No message is too urgent to be ignored.	4	12
7. No film is too good to be missed.	9	7
8. No book is too interesting to be put down.	11	5

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From Dick Margulis, for the *misnegation files*:

Some apps, such as DV



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Conclusion

- We can do proof-theoretical reasoning based on natural language representations natural logic, some spatio-temporal reasoning.
- It is not evident that switching to more powerful formalisms would be the solution for the issues discussed here.
- Grounding in real world-based models and pragmatic reasoning, might change how we think about the division of work between (limited) language-based reasoning and reasoning based on world knowledge.
- Do we have models for an integrated approach?
Johan's work gives a lot of building stones.
Gothenburg Type Theory?

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Credits

The discussion of monotonicity comes from the course we taught on Natural Logic at Stanford.

The work on spatial language was done by the NLTT group at PARC.

The investigation of the consonant/dissonance effect is joint work with Cleo Condoravdi, Stanley Peters. See:

Karttunen, L., Peters, S., Zaenen, A., Condoravdi, C.: **The chameleon-like nature of evaluative adjectives**. In: *Empirical Issues in Syntax and Semantics 10*, pp. 233–250. CSSP, Paris (2014)

We are continuing the investigation of evaluative adjectives and (some of us) would like to get back to spatial language.

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