Team semantics for natural language

The case of disjunction

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largely based on joint work with

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Overall aims of the talk

- Provide linguistic motivation for team semantics
- Show how teams — sets of worlds / assignments — can be used to capture inquisitive content
- Show why this is useful, focusing on the case of disjunction
- In particular, show that taking inquisitive content into account allows us to reconcile the two main views on disjunction in natural language semantics

An inquisitive perspective on meaning

Point of departure

- A primary function of language is to exchange information
- Language is used both to provide and to request information
- Sentences have both informative and inquisitive potential
- Semantic theories have mainly focused on informative content; inquisitive content has received far less attention

Basic aim of our research programme

- Develop a semantic framework where meanings capture both informative and inquisitive content in a uniform way

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I will illustrate the advantages of an inquisitive perspective on meaning, focusing on the case of disjunction

Two views on disjunction in natural language semantics

1. Classical view: disjunction as a join operator
2. Alternative semantics: disjunction generates alternatives

Reconciliation

- I will show that these two views can be reconciled if we adopt an inquisitive perspective on meaning
- When treated as a join operator in the inquisitive setting, disjunction automatically generates alternatives

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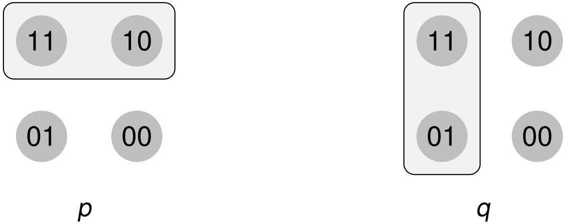
Roadmap

1. Classical treatment of disjunction as a join operator
2. Alternative semantics: disjunction generates alternatives
3. How inquisitive semantics reconciles these two views
4. Some broader repercussions for semantics and logic

(based on Roelofsen '13, Ciardelli et.al. '13a)

Propositions in classical logic

- Propositions in classical logic are sets of possible worlds

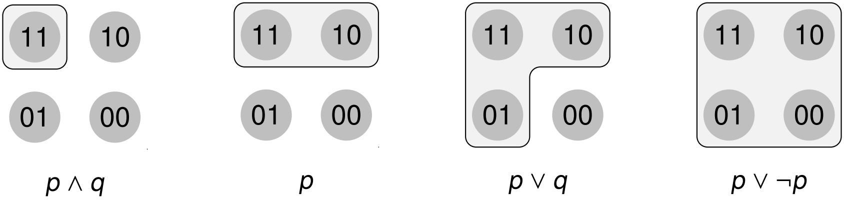


- Intuitively, a proposition carves out a region in logical space
- In asserting a sentence, a speaker provides the information that the actual world is located in this region
- In this way propositions capture informative content

Entailment

- Propositions are ordered in terms of informative strength
- One proposition is more informative than another just in case it locates the actual world within a smaller region

$$A \models B \iff A \subseteq B$$



Algebraic operations

- Every ordered set has a certain algebraic structure, and comes with certain basic algebraic operations

- The set of classical propositions, ordered by entailment, forms a complete Heyting algebra

- This means that there are three basic operations:

  1. Meet (= greatest lower bound w.r.t. entailment)
  2. Join (= least upper bound w.r.t. entailment)
  3. Relative pseudo-complementation

Connectives in classical logic

In classical logic, these basic algebraic operations are taken to be expressed by conjunction, disjunction, and implication:

- $[\varphi \wedge \psi] = [\varphi] \cap [\psi]$ meet
- $[\varphi \vee \psi] = [\varphi] \cup [\psi]$ join
- $[\varphi \rightarrow \psi] = [\varphi] \Rightarrow [\psi]$ relative pseudo-complement

And negation expresses pseudo-complementation relative to $\perp$:

- $[\neg\varphi] = [\varphi] \Rightarrow \perp$ pseudo-complement relative to $\perp$

Linguistic relevance

- It is to be expected that natural languages generally also have ways to express these basic operations on meanings
- Just like they generally have ways to express basic operations on quantities, like addition and substraction
- Certain words are indeed often taken to fulfill this purpose:

  English: and, or, if, not
  Dutch: en, of, als, niet
  Finnish: ja, tai, jos, ei
- An algebraic perspective on meaning provides a simple explanation of the cross-linguistic ubiquity of such words
- This makes classical logic, in particular the treatment of disjunction as a join operator, linguistically highly relevant

Disjunction in alternative semantics

- Recently, however, many arguments have been made for an alternative treatment of disjunction in natural language
- These arguments involve a wide range of constructions:
  - modals
  - counterfactuals
  - conditional questions
  - alternative questions
  - imperatives
  - comparatives
  - unconditionals
  - sluicing
- Claim: disjunction generates alternatives

  Kratzer & Shimoyama '02, Simons '05, Menendez-Benito '05, Alonso-Ovalle '06 '09, Aloni '07, Rawlins '08, Aloni & Port '10, AnderBois '11, Biezma & Rawlins '12, Ciardelli & Aloni '13, Aloni & Roelofsen '14, among others

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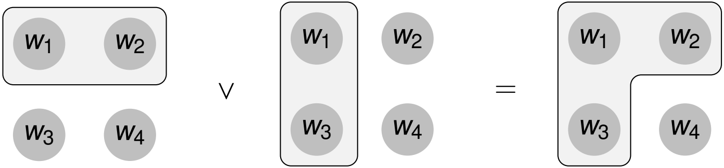
Generating alternatives

- Disjunction in classical logic:



- Disjunction in alternative semantics:

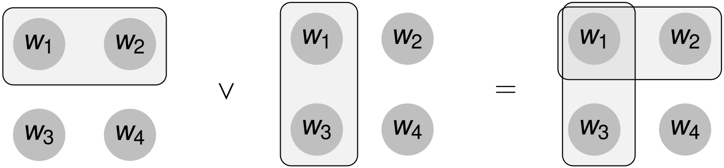


Illustration: counterfactuals

Scenario

Sally had a birthday party at her house, and some friends brought their instruments. One of her friends, Bart Balloon, has a terrible musical taste. Fortunately, he forgot to bring his trumpet.

(1) If Bart Balloon had played the trumpet,
people would have left. $\varphi > \psi$

Minimal change semantics

(Stalnaker ’68, Lewis ’73)

$\varphi > \psi$ is true in a world *w* iff among all the worlds that make φ true, those that differ minimally from *w* also make ψ true

Illustration: counterfactuals

Now consider a counterfactual with a disjunctive antecedent:

(2) If Bart Balloon or Louis Armstrong had played the trumpet, people would have left.

Prediction

- The Stalnaker/Lewis treatment of counterfactuals, together with the classical treatment of disjunction, wrongly predicts that (2) is true in the above scenario
- Intuitively, this is because all worlds that make the antecedent true and differ minimally from the actual world are ones where Bart Balloon played the trumpet, and not Louis Armstrong
- Effectively, the second disjunct is disregarded

Illustration: counterfactuals

- Initially, this observation was presented as an argument against the Stalnaker/Lewis treatment of counterfactuals

  (Fine '75, Nute '75, Ellis et.al. '77, Warmbrod '81)

- But another way to approach the problem, is to pursue an alternative treatment of disjunction

  (Alonso-Ovalle '06 '09, van Rooij '06)

  Indeed, if disjunction generates alternatives and if verifying $\varphi > \psi$ involves checking every alternative generated by φ, the problem is avoided

  (see also Franke '09, Klinedinst '09, van Rooij '10 for pragmatic solutions)

Impasse

- Many arguments that alternative semantics provides a better account of the behavior of disjunction in natural language
- However:
  - It forces us to give up the classical treatment of disjunction as expressing one of the basic algebraic operations on meanings
  - We no longer have a uniform treatment of disjunction, conjunction, implication, and negation
  - We no longer have an algebraic explanation for the cross-linguistic ubiquity of disjunction-words
- We seem to have reached an impasse

The road to reconciliation

1. Classical propositions only capture informative content
2. We will consider a team semantics in which propositions capture both informative and inquisitive content
3. We will define a corresponding notion of entailment, sensitive to both informative and inquisitive content
4. As in the classical setting, we will find that the set of all propositions, ordered by entailment, forms a Heyting algebra
5. So we will have the same basic algebraic operations: join, meet, and (relative) pseudo-complementation
6. Treating disjunction as a join operator in this richer setting gives us exactly the desired alternative generating behavior

Basic notions

Worlds and states

- Assume, as before, a universe of possible worlds W
- As usual, construe information states / pieces of information as sets of possible worlds

Common ground

- Body of shared information established in the conversation
- Modeled as an information state (Stalnaker ’78)

Propositions and utterance effects

Propositions

- A proposition is a non-empty, downward closed set of states
- Rooted in seminal work on questions (Ham'73, Kar'77, GS'84)
- But with a crucial twist: downward closure

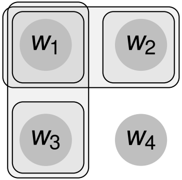
The effects of an utterance

In uttering a sentence φ, a speaker:

1. Steers the common ground towards a state in $[\varphi]$
2. Provides the information that the actual world lies in $\bigcup[\varphi]$

Example

Suppose that φ expresses the following proposition:



Then, in uttering φ, a speaker:

- Steers the common ground towards a state that is contained in $\{w_1, w_2\}$ or in $\{w_1, w_3\}$
- Provides the information that the actual world is located in $\bigcup[\varphi] = \{w_1, w_2, w_3\}$

Settling propositions and downward closure

Settling a proposition

- A piece of information α settles a proposition $\mathcal{P}$ iff mutual acceptance of α leads the cg to a state in $\mathcal{P}$
- This means that α settles $[\varphi]$ just in case $\alpha \in [\varphi]$

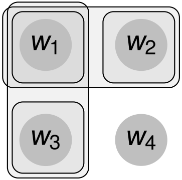
Downward closure

- We assume that if a proposition $\mathcal{P}$ is settled by α, then it is also settled by any stronger piece of information $\beta \subset \alpha$
- Therefore, propositions are required to be downward closed

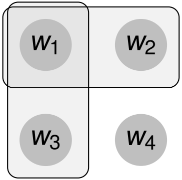
Alternatives

- Among all the states in a proposition $\mathcal{P}$, the ones that are easiest to reach are the ones that contain least information
- Visually, these states are easy to identify: they are the maximal elements of $\mathcal{P}$
- We call these states the alternatives in $\mathcal{P}$, and from now on, when visualizing propositions, we will only depict alternatives

Proposition:

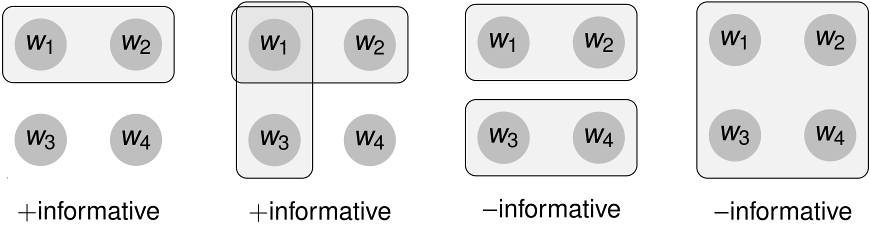


Alternatives:



Informativeness

- In uttering φ, a speaker provides the information that the actual world is contained in $\bigcup[\varphi]$
- We call $\bigcup[\varphi]$ the informative content of φ, $\text{info}(\varphi)$
- We say that φ is informative iff $\text{info}(\varphi) \neq W$



Inquisitiveness

- In uttering φ, a speaker steers the cg towards a state in $[\varphi]$
- Sometimes, all that is needed to reach such a state is mutual acceptance of info(φ)

  $\Rightarrow$ This is the case if info(φ) $\in [\varphi]$

- Otherwise, additional information needs to be provided

  $\Rightarrow$ In this case, i.e., if info(φ) $\notin [\varphi]$, we say that φ is inquisitive

Inquisitiveness and alternatives

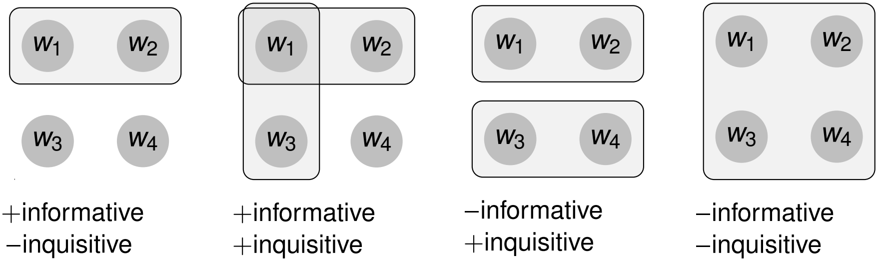
If W is finite (which is the case in all our examples):

- φ is inquisitive $\iff$ $[\varphi]$ contains at least two alternatives

Informativeness and inquisitiveness

Summary

- φ is informative $\Leftrightarrow$ $\text{info}(\varphi) \neq W$
- φ is inquisitive $\Leftrightarrow$ $\text{info}(\varphi) \notin [\varphi]$ $\Leftrightarrow_{fin}$ at least two alternatives



Entailment

Two natural conditions

In order for φ to entail ψ:

1. φ must be at least as informative as ψ: $\text{info}(\varphi) \subseteq \text{info}(\psi)$
2. φ must be at least as inquisitive as ψ: $[\varphi] \subseteq [\psi]$

   (every piece of information that settles $[\varphi]$ also settles $[\psi]$)

Simplification

- The second condition implies the first
- So: $\varphi \models \psi \iff [\varphi] \subseteq [\psi]$

Algebraic operations

- Just as in the classical setting, the set of all propositions, ordered by entailment, forms a complete Heyting algebra
- This means that we have the same basic operations:

  1. Meet
  2. Join
  3. Relative pseudo-complementation

Basic inquisitive semantics

As before, conjunction, disjunction, implication & negation can be taken to express these basic algebraic operations:

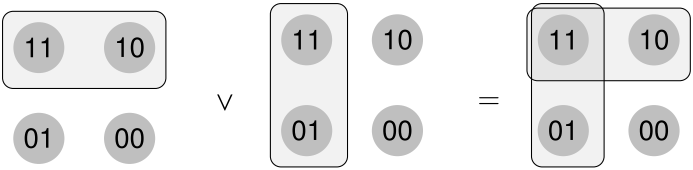
- $[\varphi \wedge \psi] = [\varphi] \cap [\psi]$ meet
- $[\varphi \vee \psi] = [\varphi] \cup [\psi]$ join
- $[\varphi \rightarrow \psi] = [\varphi] \Rightarrow [\psi]$ relative pseudo-complement
- $[\neg\varphi] = [\varphi] \Rightarrow \bot$ pseudo-complement relative to $\bot$

$\Rightarrow$ We enriched the notion of meaning, but we preserved the essence of the classical treatment of the connectives

These connectives have also been considered in dependence logic, see e.g. Abramsky and Väänänen '09, Yang '14. However, the standard DL treatment of disjunction is actually quite different.

Disjunction generates alternatives

- When treated as a join operator in the inquisitive setting, disjunction has exactly the alternative generating behavior that is assumed in alternative semantics



Interim summary

- The treatment of disjunction in alternative semantics can be reconciled with the classical treatment of disjunction as join
- In the inquisitive setting, the two essentially coincide
- All the phenomena dealt with in alternative semantics can be accounted for without giving up the idea that disjunction expresses one of the basic algebraic operations on meanings
- One concrete case: the Stalnaker/Lewis account of counter-factuals is compatible with treating disjunction as join

  (contra the general assumption since Fine ’75, Nute ’75, Ellis et.al. ’77)

Roadmap

1. Classical treatment of disjunction as a join operator
2. Alternative semantics: disjunction generates alternatives
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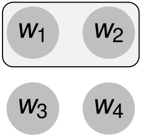
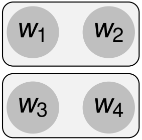
Uniform treatment of declaratives and interrogatives

The inquisitive framework presented here allows for a uniform semantic treatment of declaratives and interrogatives

(3) Carla speaks Spanish.



(4) Does Carla speak Spanish?

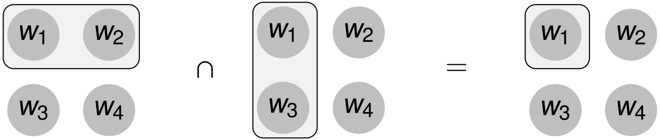


Logical operations apply uniformly to both types of sentences

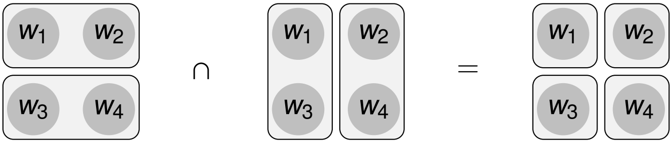
(Ciardelli, Groenendijk & Roelofsen ’13b)

Uniform treatment of conjunction

(5) Carla speaks Spanish and she speaks French.

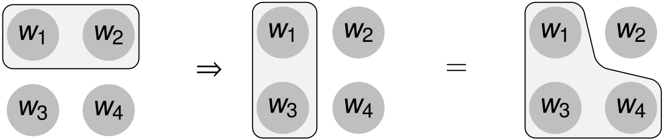


(6) Does Carla speak Spanish, and does she speak French?

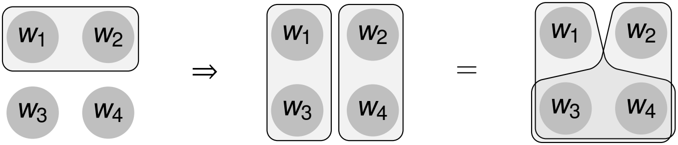


Uniform treatment of conditionals

(7) If John goes to the party, Mary will go as well.



(8) If John goes to the party, will Mary go as well?



Generalized entailment

- Entailment applies uniformly to declaratives and interrogatives

Declarative entails declarative:	Everyone left $\models$ Bill left
Declarative entails interrogative:	Everyone left $\models$ Who left?
Interrogative entails interrogative:	Who left? $\models$ Did Bill leave?

- So entailment is no longer just about inference, but also about resolution and subquestions
- In the propositional setting, entailment can be axiomatized by extending intuitionistic logic with:

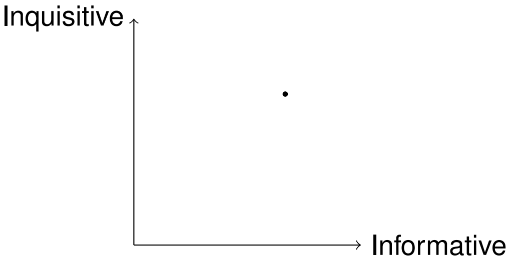
  1. Atomic double negation: $\neg\neg p \rightarrow p$
  2. Kreisel-Putnam: $(\neg\chi \rightarrow \varphi \vee \psi) \rightarrow (\neg\chi \rightarrow \varphi) \vee (\neg\chi \rightarrow \psi)$

- The first-order completeness problem is still open.

(Ciardelli '09, Ciardelli & Roelofsen '11)

Projection operators

- Propositions inhabit a two-dimensional space:



- We can define projection operators that obliterate one dimension of meaning, while leaving the other intact
- This can be done in terms of our basic algebraic operations

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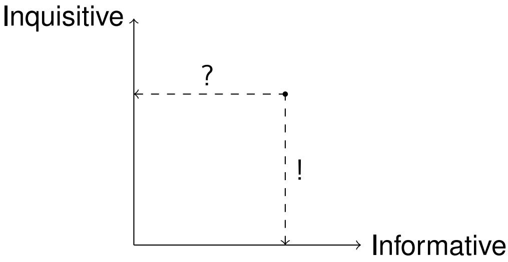

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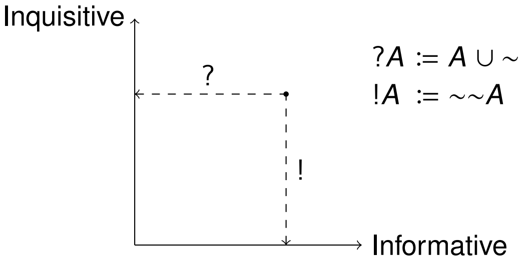

$$?A := A \cup {\sim}A$$
$$!A := {\sim}{\sim}A$$

- We can define projection operators that obliterate one dimension of meaning, while leaving the other intact
- This can be done in terms of our basic algebraic operations

Projection operators in natural language

- It may be expected that natural languages generally have ways to express these projection operators
- Indeed, this is precisely what declarative and interrogative clause type markers may be taken to do

(9) Hector knows that Achilles left. that = !

(10) Hector knows whether Achilles left. whether = ?

Disclaimer

- This is a first approximation that only works for simple cases
- The semantics of interrogative clause type markers is actually a bit more complex, especially in interaction with disjunction, but the projection operators do play an important role

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Conclusion

An inquisitive perspective on meaning:

- Has given rise to a semantic framework in which formulas are evaluated relative to a set of worlds / assignments, rather than a single world / assignment, just as in dependence logic
- Allows us to reconcile two prominent views on disjunction, and yields a principled treatment of other connectives as well
- Facilitates a uniform semantic treatment of declarative and interrogative sentences, and combinations thereof
- Provides richer logical foundations for the analysis of information exchange through linguistic communication

Thank you

For a handout version of these slides, including references, see:

www.illc.uva.nl/inquisitivesemantics