

# Knowledge Representation

## *Conceptual Dependency*

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Based on the work done by Roger Schank and his group at Yale University in the 1970s.

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# Perception / Understanding

Making sense of some inputs.

Natural Language Understanding

Speech Understanding

Image Understanding

Understanding is like parsing.

Thesis : Understanding has a strong top down component.  
It involves concept driven mapping into preconceived notions, rather than data driven bottom up approach.

## A short story

From "Identification of Conceptualizations underlying Natural Language" – Roger Schank

John meets Fred on the road. Fred has a knife. John is angry because his wife Mary has yelled at him...

*Fred* : Hi

*John* : What are you doing with the knife?

*Fred* : Thought I'd teach the kids to play mumbly-peg.

*John* : I could use a knife right now.

*Fred* : What's the matter?

*John* : Damn Mary, always on my back. She'll be sorry.

*Fred* : I don't think a knife will help you.

*John* : You're just on her side. I think I ought to . . .

... at this point the listener has some expectations

## Expectations

Syntax	a verb
Meaning	a "conceptual structure" type and a filler for it
Context	the conceptual structure predicts an "action". Context delimits the range of possible actions, for example      end relationship hurt someone go to some place emote
Conversational	people talk for a reason. To arouse sympathy, or to inform about intent, etcetra...
World view of listener	If John is known to be a convicted murderer the expectation would be different from if he were known to be an avowed pacifist.
Cultural norm	what is accepted within a culture

What kind of knowledge structures in memory would generate such expectations?

## A short story

John meets Fred on the road. Fred has a knife. John is angry because his wife Mary has yelled at him...

*Fred* : Hi

*John* : What are you doing with the knife?

*Fred* : Thought I'd teach the kids to play mumbly-peg.

*John* : I could use a knife right now.

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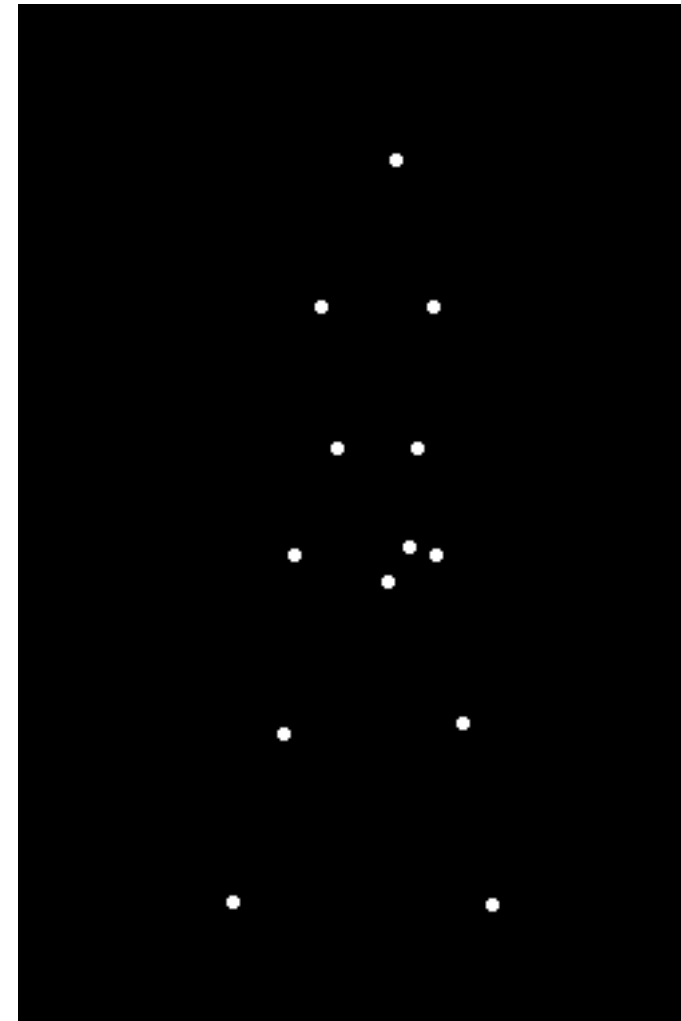
*Fred* : I don't think a knife will help you.

*John* : You're just on her side. I think I ought to . . .

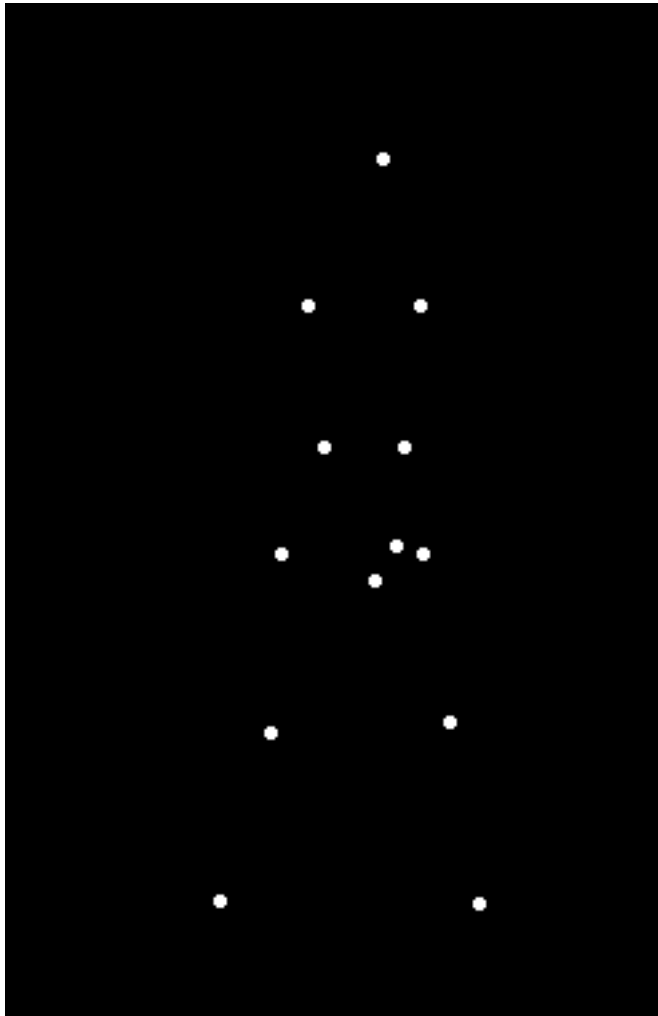
One would be considerably surprised to hear  
"I think I ought to go and eat some fish"

Jokes exploit such  
violation of expectation.

# Vision..



Courtesy: Richard Gregory







# Conceptual Dependency Theory

- The CD theory defines a **semantic base** for knowledge representation.
- The objective was to *understand* natural language stories.
- The CD theory is designed for *everyday* actions.
- More specific domains would require a specific set of primitives.

Basic unit → CONCEPTUALIZATION

something like a Well Formed Formula

Main component → EVENT defined by

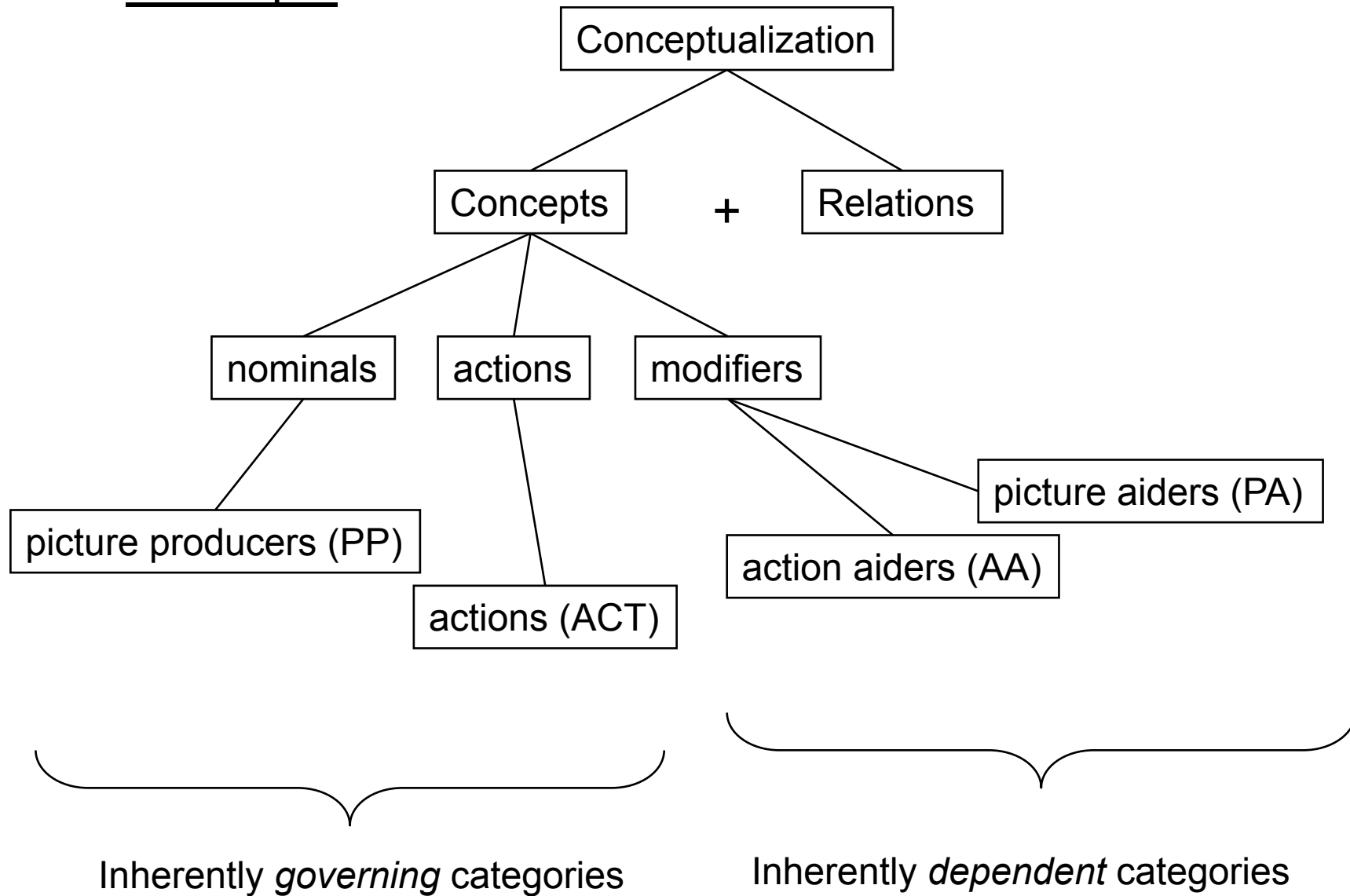
an ACTOR

an ACTION

an OBJECT

a sense of DIRECTION

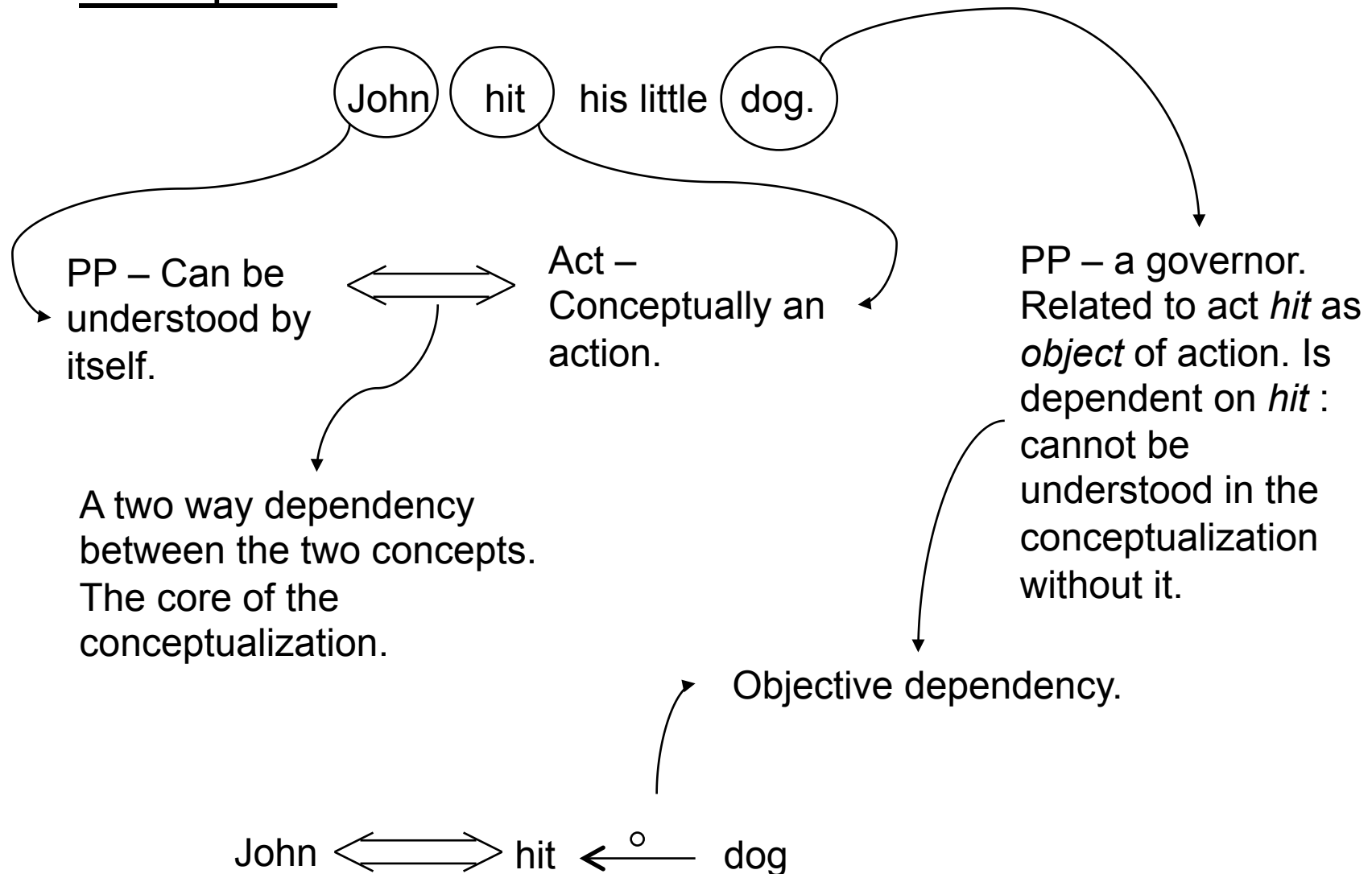
# Concepts



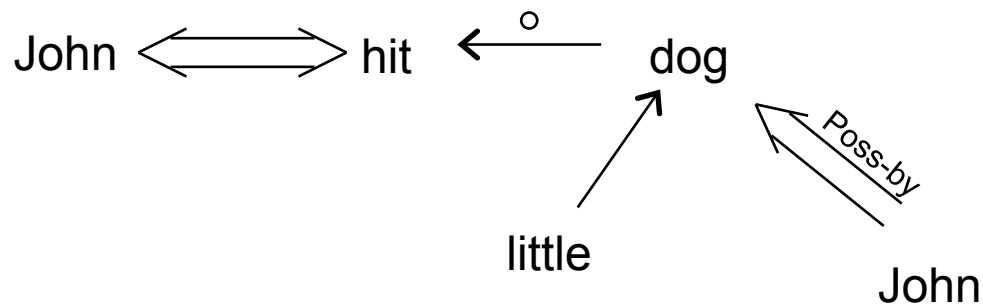
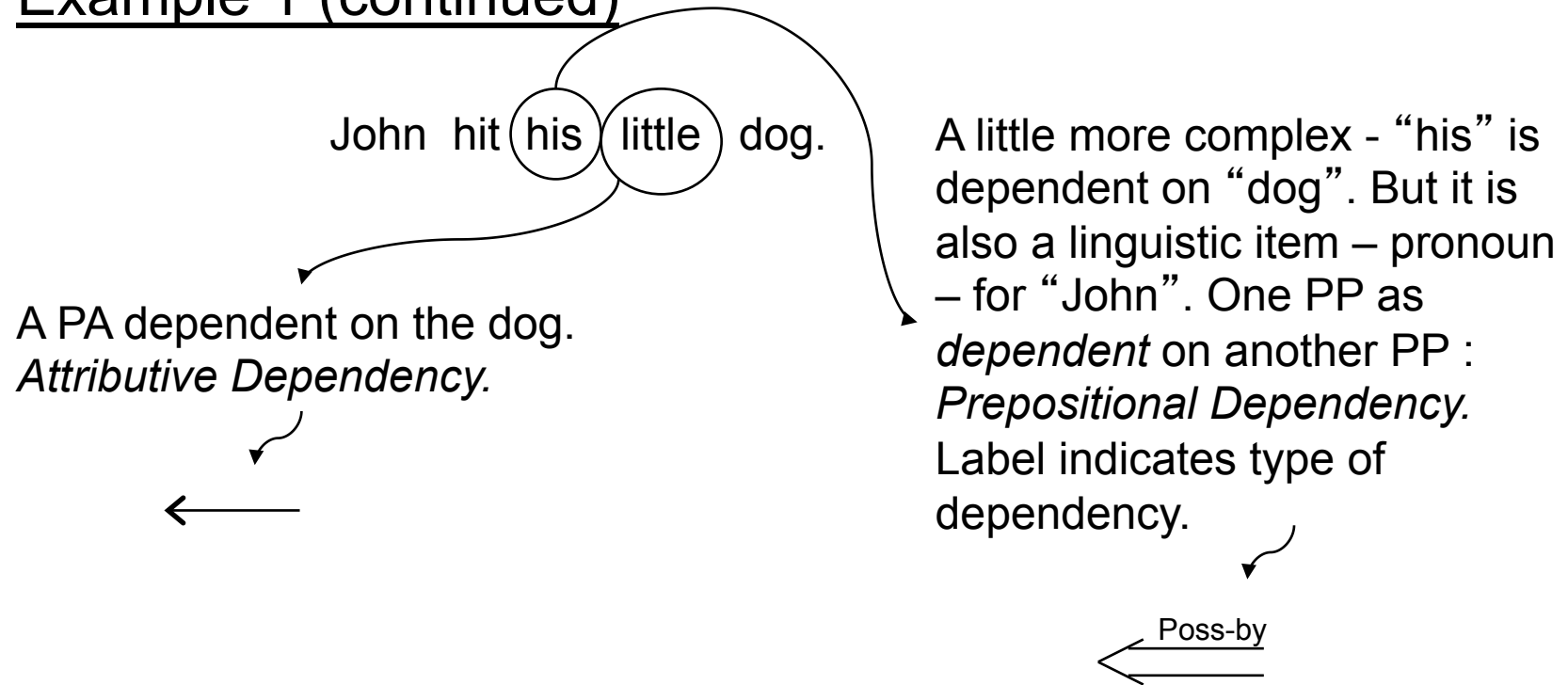
# Conceptualizations

- Nominals and actions can exist as independent notions.
  - Nominals stand for objects and people.
  - Actions are acts of nominals.
- Modifiers give additional information on the nominals or actions.
- A dependent concept *predicts* the existence of a governor.
- A conceptualization is a collection of concepts and relations in which there is at least a *two way dependency*.
- A conceptualization tells you something about the world.
- Conceptual Dependency theory defines the set of actions that can be done by people.
- Can be described in a logic like syntax
  - For example in “Artificial Intelligence”, by Charniak and McDermott.
- Can be depicted graphically by C-diagrams.

# Example 1.



## Example 1 (continued)



# Time

# Conceptual Dependencies

1. PP  $\longleftrightarrow$  ACT

Certain PPs can ACT

2. PP  $\longleftrightarrow$  PA

PPs (and some Conceptualizations) can be described by an attribute.

3. ACT  $\xleftarrow{\circ}$  PP

ACTs have objects.

4. ACT  $\xleftarrow{D}$   $\begin{cases} \rightarrow \text{LOC} \\ \leftarrow \text{LOC} \end{cases}$

ACTs have direction.

5. ACT  $\xleftarrow{R}$   $\begin{cases} \rightarrow \text{PP} \\ \leftarrow \text{PP} \end{cases}$

ACTs have recipients..

6. ACT  $\xleftarrow{\circ}$   $\updownarrow$

MTRANS requires conceptualizations as objects, and MBUILD has its own object type.

# Conceptual Dependencies

PP  $\longleftrightarrow$  ACT

PP  $\longleftrightarrow$  PA

ACT  $\xleftarrow{\circ}$  PP

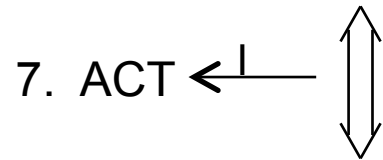
ACT  $\xleftarrow{D}$  LOC

ACT  $\xleftarrow{R}$  PP

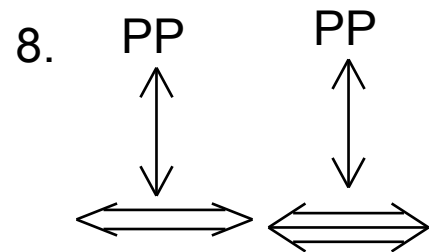
ACT  $\xleftarrow{\circ}$   $\updownarrow$



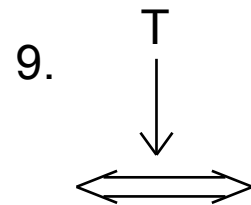
# Conceptual Dependencies



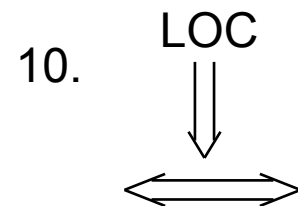
ACTs have conceptualizations as instruments.



PPs can be described by the conceptualizations in which they occur.

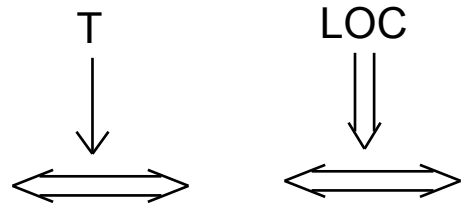
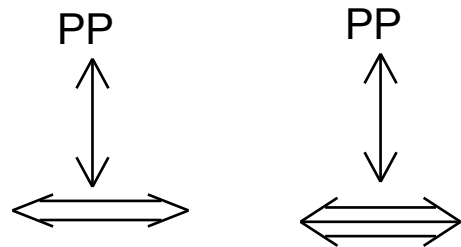
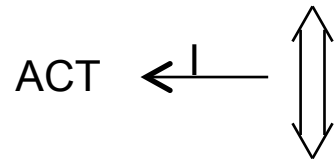


Conceptualizations have times.

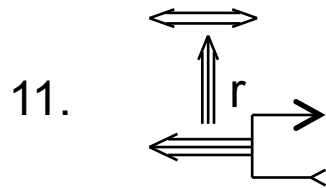


Conceptualizations have locations.

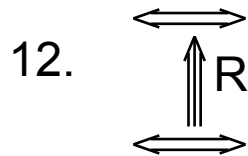
# Conceptual Dependencies



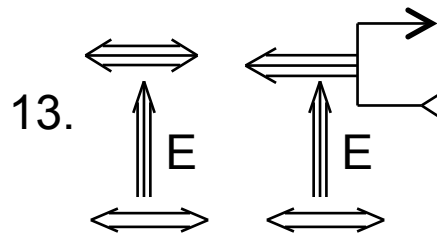
# Conceptual Dependencies



Conceptualizations can *result* in state changes for PPs.



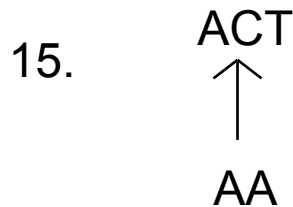
Conceptualizations involving mental ACTs can server as *reasons* for conceptualizations.



State or state changes can *enable* conceptualizations to occur.

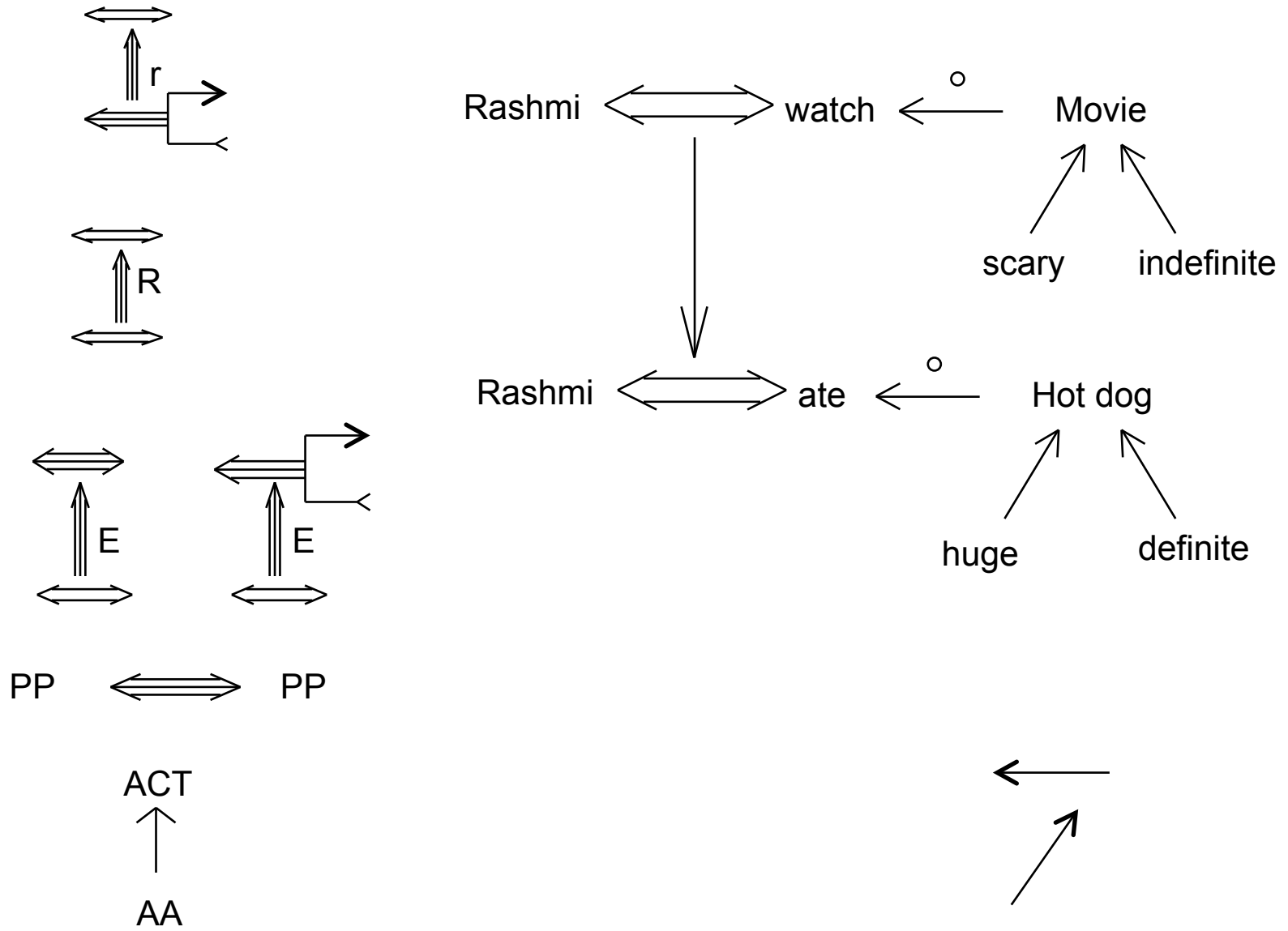


One PP is equivalent to or an instance of another PP.

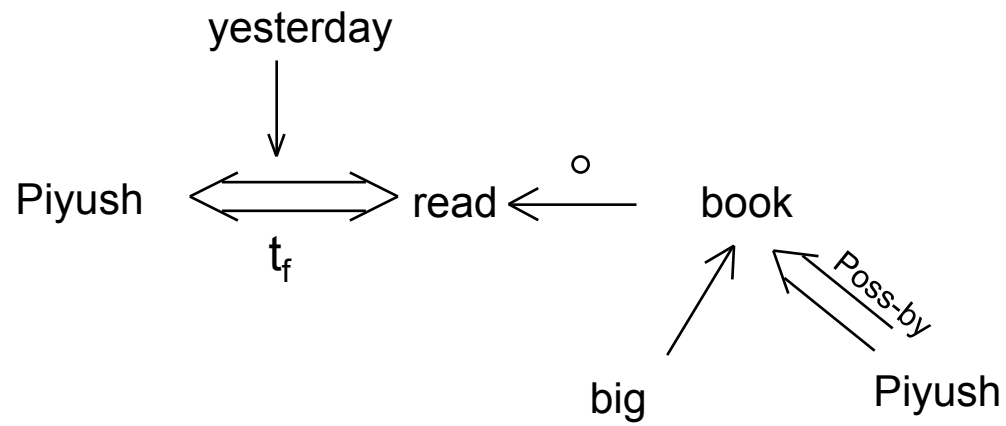


ACTs can be varied along certain dimensions (e.g. speed for motions ACTS).

# Conceptual Dependencies



# Conceptual Dependencies



## State Variables

HEALTH: goes from -10 to +10

<i>Examples:</i>	dead	-10
	gravely ill	-9
	sick	-9 to -1
	under the weather	-2
	all right	0
	tip top	+7
	perfect health	+10

PHYSICAL STATE: goes from -10 to +10

<i>Examples:</i>	dead	-10
	harmed	-9
	injured	-5
	broken (for objects)	-5
	harmed	-1 to -7
	hurt	-1 to -7
	OK	10

## State Variables

ANGER : goes from -10 to 0

*Examples:*

furious	-9
enraged	-8
angry	-5
irked	-3
upset	-2
calm	0

MENTAL STATE: goes from -10 to +10.

*Examples:*

(same as JOY in MARGIE)

catatonic	-9
depressed	-5
upset	-3
sad	-2
OK	0
pleased	+2
happy	+5
ecstatic	+10

## State Variables

FEAR : goes from -10 to 0

<i>Examples:</i>	terrified	-9
	scared	-5
	anxious	-2
	calm	0

CONSCIOUSNESS: goes from 0 to +10

<i>Examples:</i>	unconscious	0
	asleep	5
	awake	10
	“higher drug consciousness”	> 10

SURPRISE : goes from 0 to 10

<i>Examples:</i>	surprised	5
	amazed	7
	astounded	9



## State Variables

HUNGER: goes from -10 to +10.

*Examples:*

Starving	-8
ravenous	-6
“could eat a horse”	-5
hungry	-3
no appetite	0
satisfied	3
full	5
stuffed	8
satiated	3 - 10

DISGUST : goes from -10 to 0

*Examples:*

nauseated	-8
revolted	-7
disgusted	-6
bothered	-2

## Compound states

- shocked = SURPRISE (6)  
DISGUST (-5)
- calm/cool = SURPRISE (0)  
DISGUST (0)  
FEAR (0)  
ANGER (0)  
CONSCIOUSNESS (>0)

## Margie : Inference mode

INPUT : John told Mary that Bill wants a book.

*OUTPUT 1 : A book about what?*

*OUTPUT 2 : Mary knows that Bill wants a book.*

*OUTPUT 3 : Bill wants to come to have a book.*

*OUTPUT 4 : Bill wants someone to cease to have a book.*

*OUTPUT 5 : Bill wants to read a book.*

INPUT : John gave Mary a beating with a stick.

*OUTPUT 1 : A stick touched Mary.*

*OUTPUT 2 : Mary became hurt.*

*OUTPUT 3 : John wanted Mary to become hurt.*

*OUTPUT 4 : Why was John angry?*

## Margie : Inference mode

INPUT : John gave Mary an aspirin.

*OUTPUT 1 : John believes that Mary wants an aspirin.*

*OUTPUT 2 : Mary is sick.*

*OUTPUT 3 : Mary wants to feel better.*

*OUTPUT 4 : Mary will ingest the aspirin.*

INPUT : John is going to go to the store.

*OUTPUT 1 : John wants to be at the store.*

*OUTPUT 2 : What does John want to buy?*

*OUTPUT 3 : John will trade money to the store for something.*

## Margie : Paraphrase mode

INPUT : John advised Mary to drink the wine.

OUTPUT : *John told Mary that drinking the wine would benefit her.*

INPUT : John killed Mary by choking Mary.

OUTPUT 1 : *John strangled Mary.*

OUTPUT 2 : *John choked Mary and she died because she could not breathe.*

## Margie : Paraphrase mode

INPUT : Reading the book reminded Rita to loan the book to Bill.

OUTPUT : *Rita remembered to give the book to Bill and she expects him to return it to her because someone read the book.*

INPUT : John prevented Bill from giving a banana to Mary by selling a banana to Rita.

OUTPUT 1 : *Bill was unable to give a banana to Mary because Rita traded John some money for a banana.*

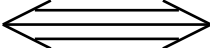
OUTPUT 2 : *Mary could not get a banana from Bill because Rita bought a banana from John.*

# Conceptual Dependency Theory

Representation of the *meaning* of sentences. Basic axioms-

1. For two sentences with identical meaning, regardless of language, there should be only one representation.
2. Any information that is implicit in the sentence must be made explicit in the representation (via inferences).
3. The meaning propositions underlying language are called conceptualizations – active or stative.

4. Active → Actor Action Object Direction (Instrument) 

5. Stative → Object (is in) State (with Value). 

## Margie : Inferences

- Specification Inferences

John picked up a rock.

He hit Bill.

JOHN HIT BILL WITH THE ROCK.

John and Bill were alone on a desert island.

Bill was tapped on the shoulder.

JOHN TAPPED BILL.

- Causative Inferences

John hit Mary with a rock.

JOHN WAS PROBABLY MAD AT MARY.

- Resultative Inferences

Mary gave John a car.

JOHN HAS THE CAR.



## Inferences (continued)

- Motivational Inferences

John hit Mary.

JOHN PROBABLY WANTED MARY TO BE HURT.

- Enablement Inferences

Pete went to Europe.

WHERE DID HE GET THE MONEY?

- Function Inferences

John wants the book.

JOHN PROBABLY WANTS TO READ IT.

- Enablement-Prediction Inferences

Dick looked in his cook book to find out how to make a roux.

DICK WILL NOW BEGIN TO MAKE A ROUX.

## Inferences (continued)

- Missing Enablement Inferences

Mary couldn't see the horses finish.

She cursed the man in front of her.

THE MAN BLOCKED HER VISION.

- Intervention Inferences

The baby ran into the street.

Mary ran after him.

MARY WANTS TO PREVENT THE BABY  
FROM GETTING HURT.

- Action Prediction Inferences

John wanted some nails.

HE WENT TO THE HARDWARE STORE.

## Inferences (continued)

- Knowledge-Propogation Inferences

Pete told Bill that Mary hit John with a bat.

BILL KNEW THAT JOHN HAD BEEN HURT.

- Normative Inferences

Does Pete have a gall bladder?

ITS HIGHLY LIKELY.

John saw Mary at the beach Tuesday morning.

WHY WASN' T SHE AT WORK?

- State Duration Inferences

John handed a book to Mary yesterday.

Is Mary still holding it?

PROBABLY NOT.

## Inferences (continued)

- Feature Inferences

Andy's diaper is wet.

ANDY IS PROBABLY A BABY.

- Situation Inferences

Mary is going to a masquerade.

SHE WILL PROBABLY WEAR A COSTUME.

- Utterance-Intent Inferences

Mary couldn't jump the fence.

WHY DID SHE WANT TO?

## Heuristics for inferences

1. John drooled as he viewed the banana. He ate
  - FILL IN THE BANANA AS THE CONCEPTUAL OBJECT OF EATING.
  
2. Pete and Bill were alone on a desert island. Someone tapped Bill on the shoulder.
  - FILL IN PETE AS THE CONCEPTUAL ACTOR OF “MOVE” WHICH UNDERLIES “TAP”
  
3. Mary picked up the rock. She hit John.
  - PREDICT THAT IT WAS THE ROCK WAS THE OBJECT OF MARY’ S PROPELLING ACT

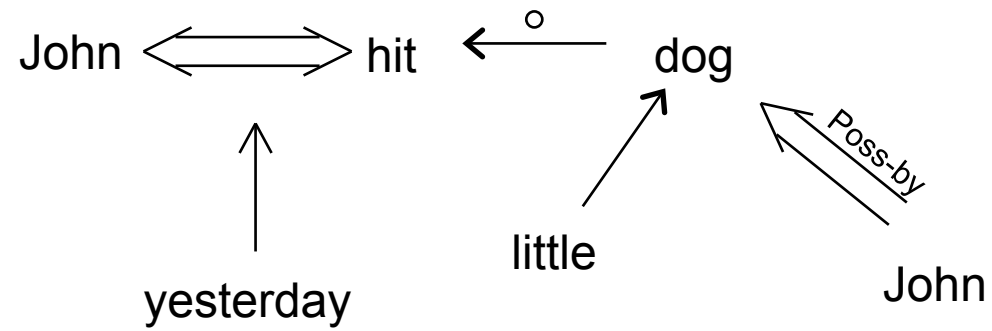
## Heuristics (continued)

4. John was driving his car. He hit Mary.
  - PREDICT THE CAR AS THE OBJECT OF THE PROPEL.
  
5. John bought a hammer.
  - “BUY” IS UNDERLIED BY A DUAL ATRANS ACT. WHO IS THE OTHER ACTOR?
  
6. John was asleep.
  - WHAT IS THE LOCATION OF THIS COMMON STATE LIKELY TO BE IN THE ABSENCE OF OTHER EXPLICIT INFORMATION?

## Heuristics (continued)

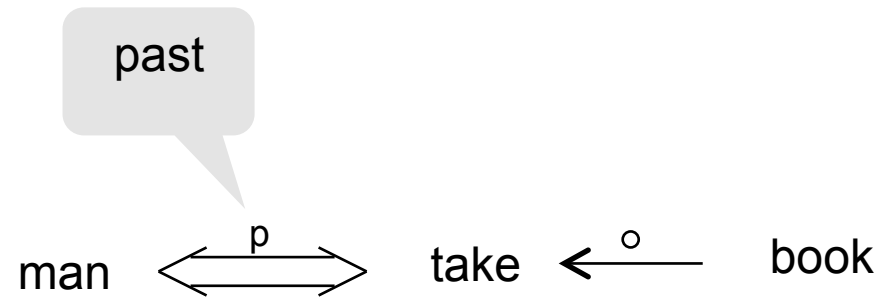
7. Mary went to work.
  - WHAT IS THE TIME OF THIS COMMON ACTION LIKELY TO BE?
  
8. John went to Paris.
  - PREDICT THE LIKELY INSTRUMENTALITY “FLY”.

# Yesterday, John hit his little dog





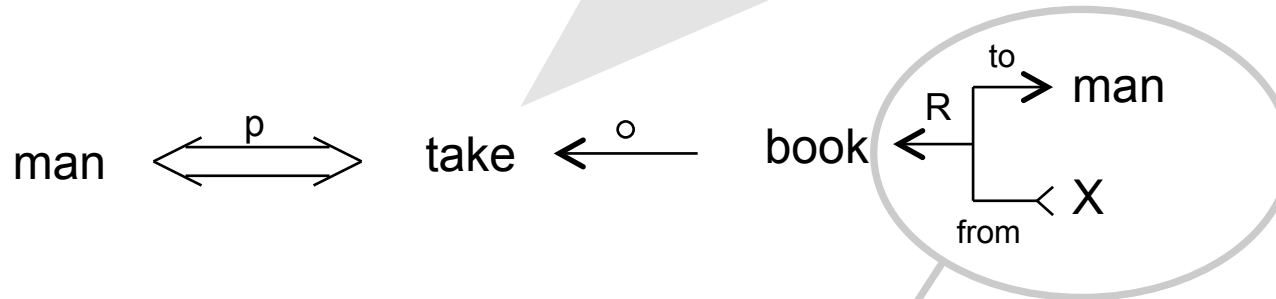
The man took a book.



But he must have taken the book from someone.

# The man took a book.

Here we have taken the linguistic verb "take" itself as a conceptual ACT



An explicit conceptual Case Marker

Like *Kaarak* case markers in Panini grammar

"Karta ney", "Karma ko", ...

# Conceptual Cases

ACT  $\xleftarrow{\circ}$  PP

Objective case

ACT  $\xleftarrow{D}$   $\begin{cases} \rightarrow \text{LOC} \\ \leftarrow \text{LOC} \end{cases}$

Directive case

ACT  $\xleftarrow{R}$   $\begin{cases} \rightarrow \text{PP} \\ \leftarrow \text{PP} \end{cases}$

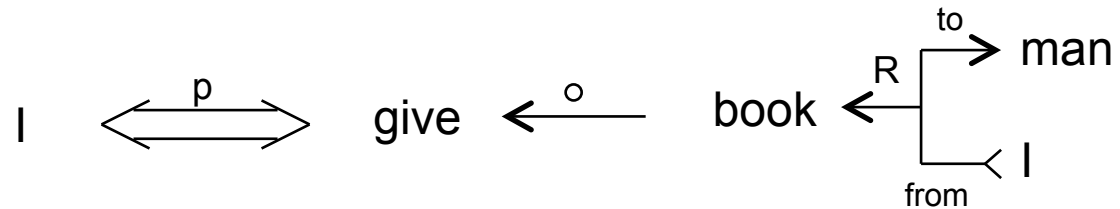
Recipient case

ACT  $\xleftarrow{I}$   $\updownarrow$

Instrumental case

Conceptual cases are predictive mechanisms. They create slots that need to be filled up. The conceptualization is incomplete till they have been filled. Dialogs are often sustained by the process of filling up empty slots.

# I gave the man a book

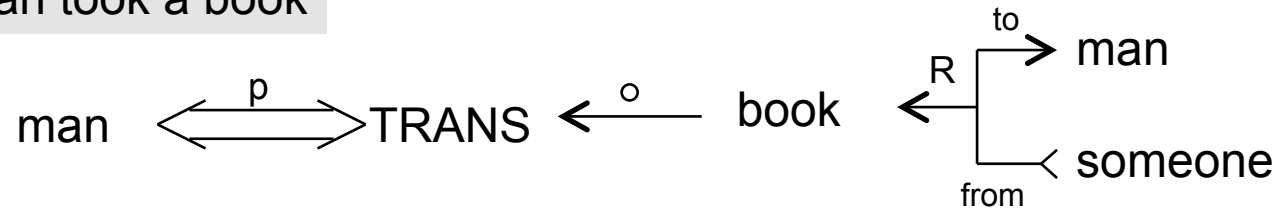


Conceptually "giving" and "taking" both involve transfer of something.

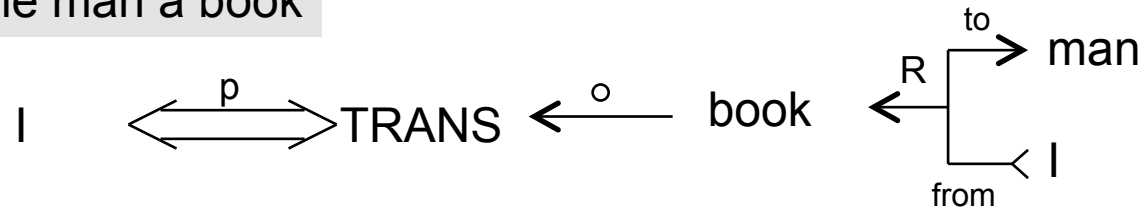
Only the ACTOR is different.

# TRANS (fer)

The man took a book



I gave the man a book

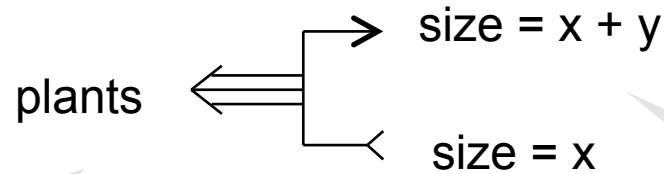


The underlying conceptual act behind give and take is TRANS

John grew the plants with fertilizer

Two events are happening here

Linguistically fertilizer is the instrument.



State change event

The plants growing ...

Conceptual action

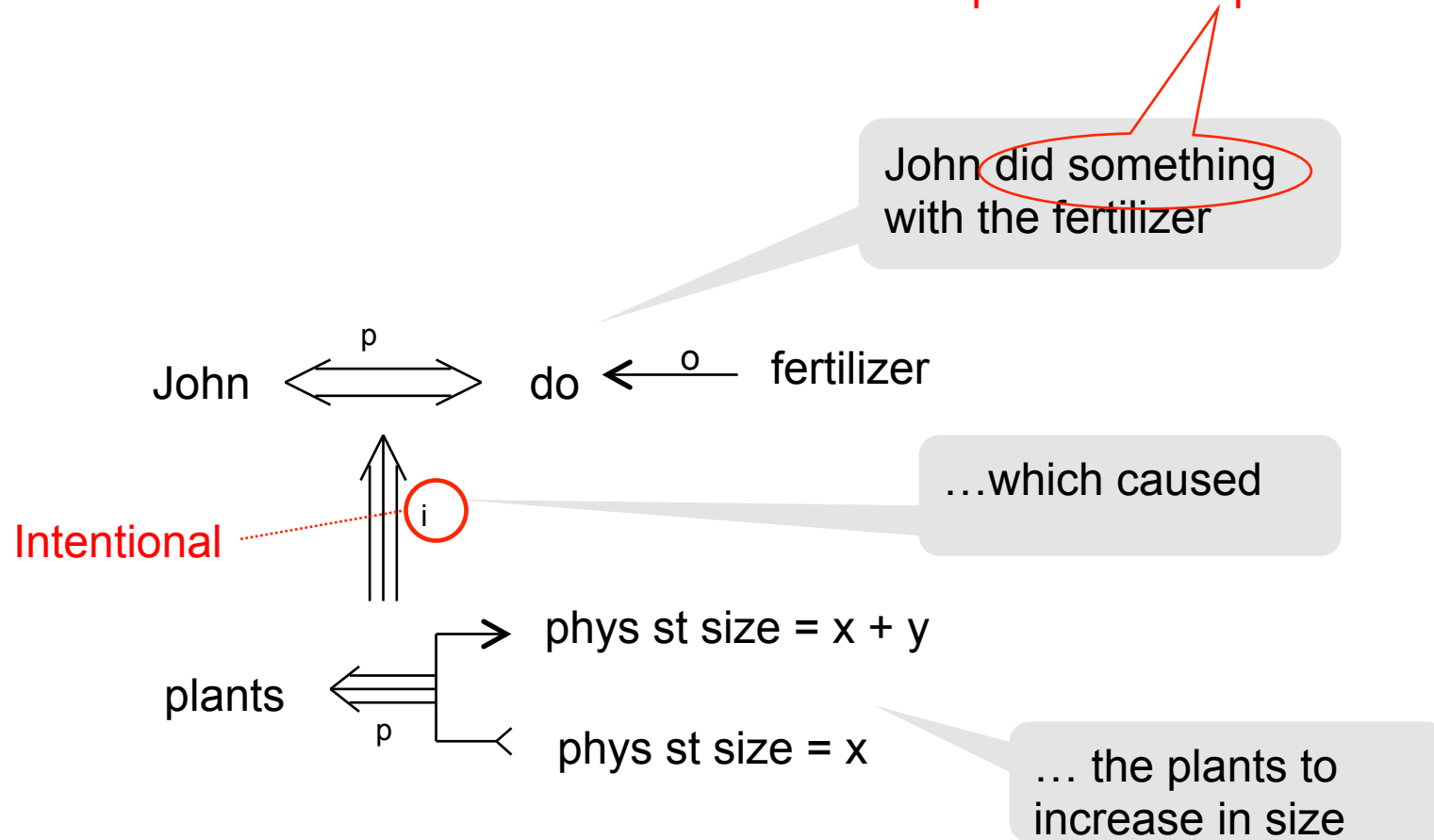


... and John doing something

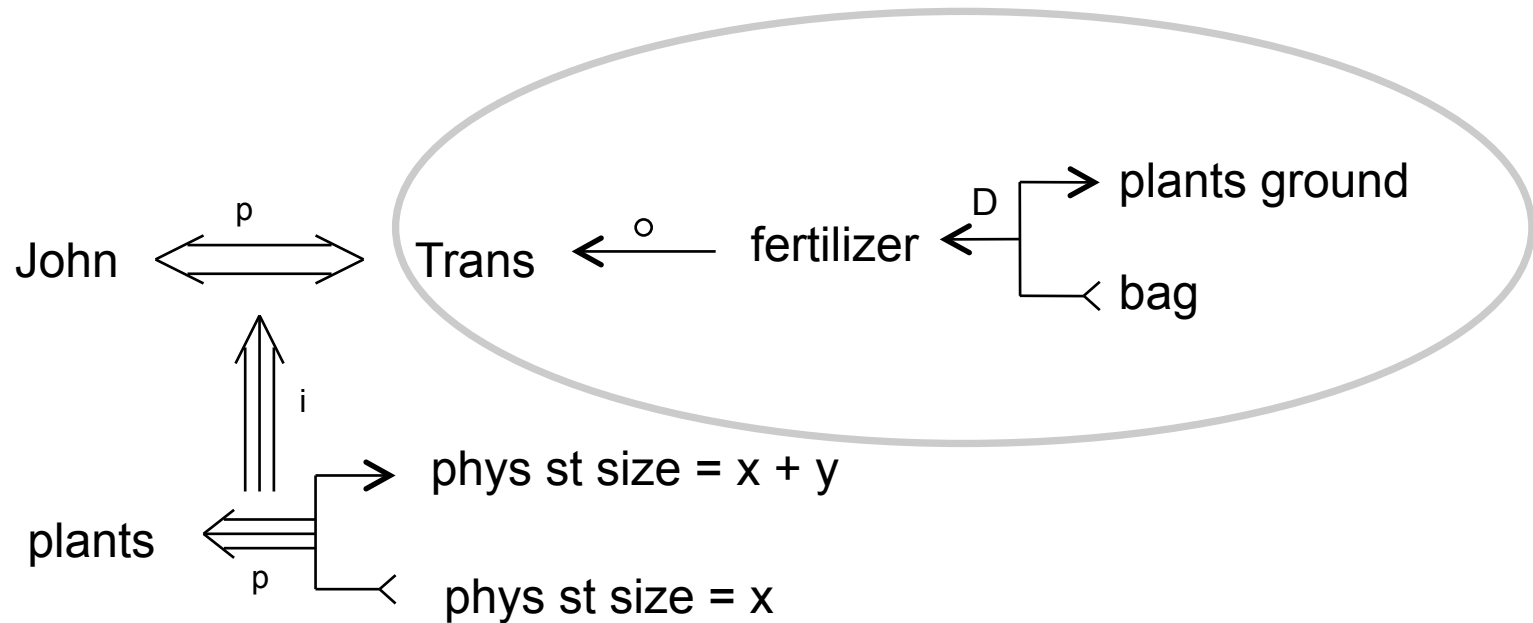
Conceptually it is the Object of some act.

# A Causal Connection

A more informed listener might create a more specific conceptual structure.



## ... John transferred the fertilizer





## CD actions

- **ATRANS**     The transfer of an abstract relationship such as possession, ownership or control.
  - Give, take, buy...
- **PTRANS**     Transfer of physical location of an object.
  - Go, put...
- **PROPEL**     Application of physical force to an object (regardless of whether the object is PTRANSed or not).
  - Push, pull, throw, kick have PROPEL as part of them.
- **MOVE**         The movement of a body part of an animal by that animal. Often an instrumental act.
  - MOVE foot is the instrument in kick.

## CD actions (continued)

- **GRASP**      The grasping of an object by an actor
  - Verbs grab, let go, and throw involve GRASP
- **INGEST**      to take in
  - Eat, drink, smoke, breathe...
- **EXPEL**      expulsion from the body...
  - Including sweat, spit, and cry...
- **MTRANS**      The transfer of mental information between animals or within an animal. Memory partitions – CP (conscious processor) and LTM (long term memory)
  - Tell – MTRANS between people
  - See – MTRANS from eyes to CP
  - Remember – MTRANS from LTM to CP

## More CD actions

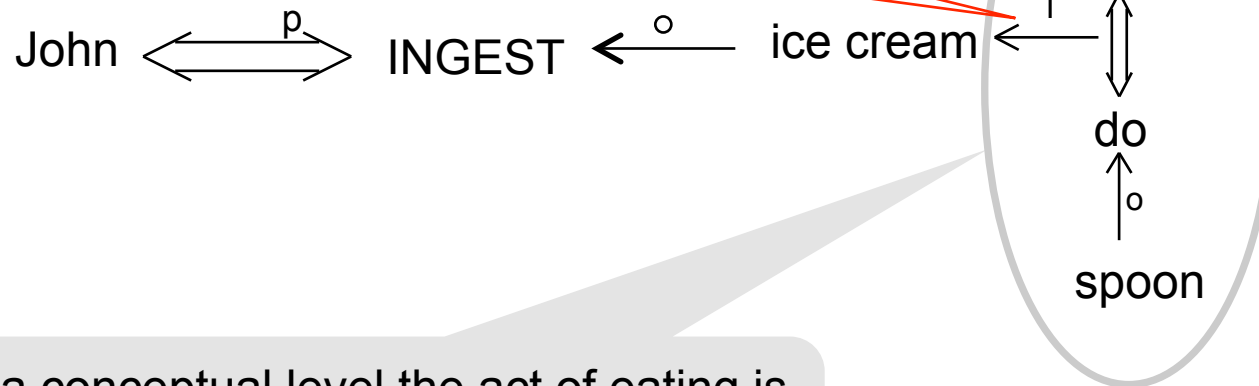
- **MBUILD**      The construction by an animal of new information from old information.
  - Decide, conclude, imagine, consider...
- **SPEAK**      The actions of producing sounds. Humans often use it as an instrument for MTRANS.
  - Say, play music, purr, scream involve SPEAK
- **ATTEND**      The action of attending or focusing a sense organ towards a stimulus. Also an instrument to MTRANS.
  - See is MTRANS to CP from eye by instrument of ATTEND eye to object.
  - Listen is ATTEND ear

# Instruments

John ate the ice cream with a spoon

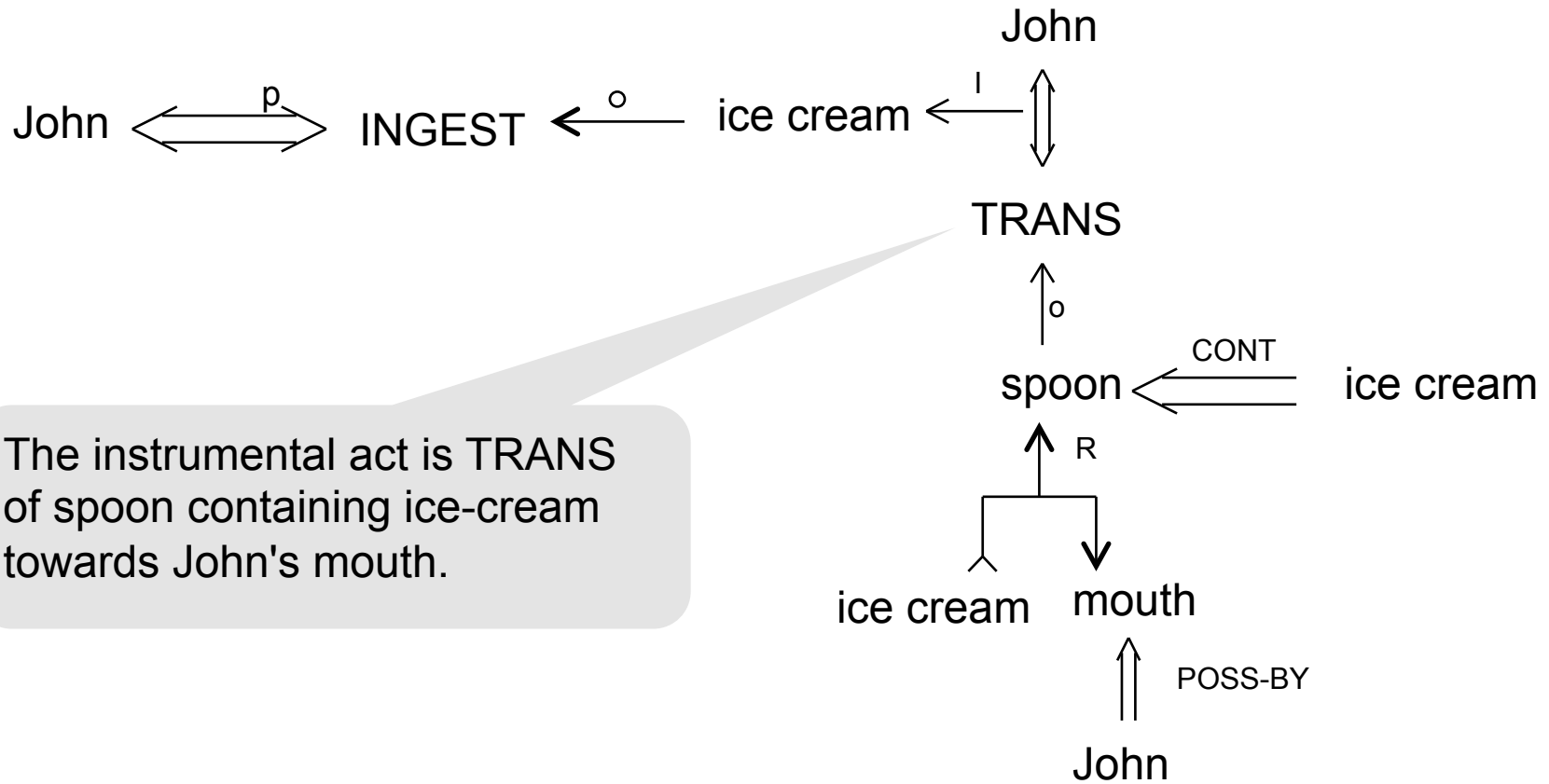
Linguistically the spoon is the instrument with which John ate.

Note: arrow meant for ACT



At a conceptual level the act of eating is enabled by an instrumental act that uses the spoon as an object.

# Eating with a spoon



The instrumental act is TRANS of spoon containing ice-cream towards John's mouth.

## Instrumental Acts

Every ACT can have an instrumental ACT. For example,

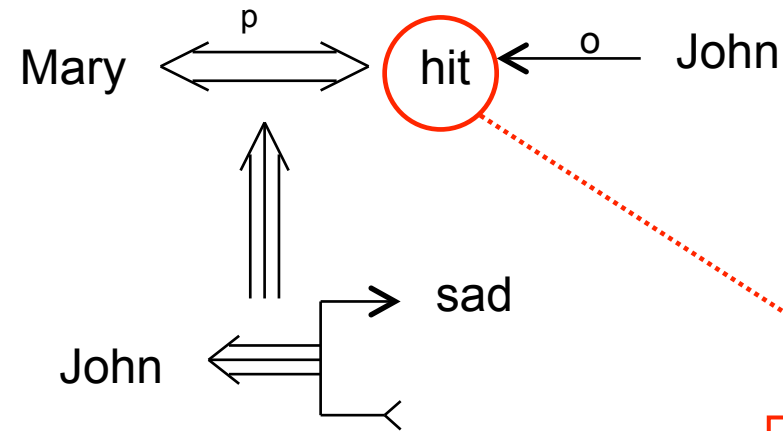
John ingested the icecream, by TRANSing the spoon towards his mouth, which he did by grasping the spoon and then moving his hand, by flexing his muscles, by thinking about flexing his muscles, ...

... we truncate our causal reasoning and instrumental case specification at a granularity suited to our task.

In any domain that we build a conceptual representation system for we will have to choose an appropriate level for primitive actions.

# John was sad because Mary hit him

Another example of an ACT causing a state change.

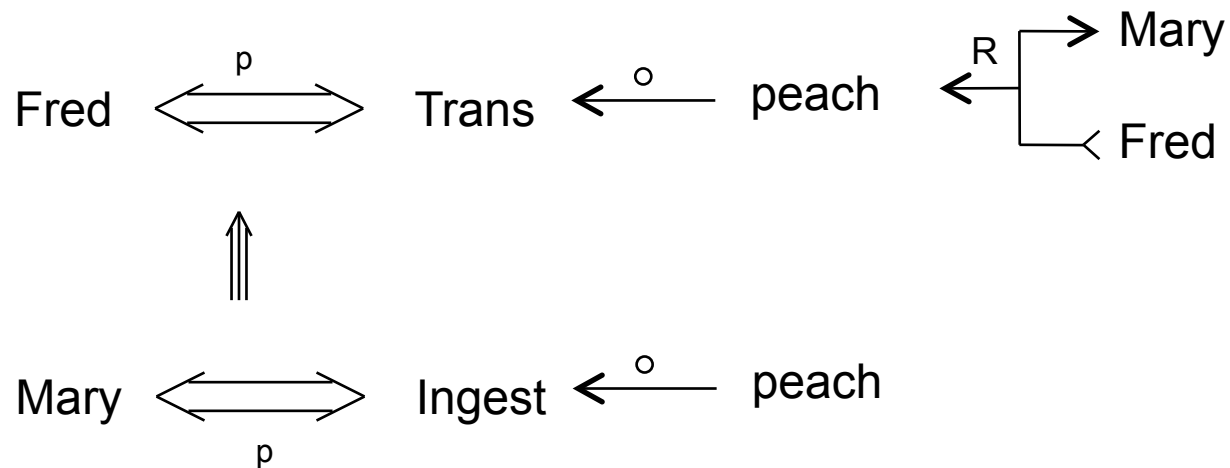


Not a CD Act !

In CD theory **hit** would be modeled as coming into a **state** of being in forceful contact, with PROPEL being the basic ACT and MOVE the instrumental ACT.

## Events can cause other events

When Fred gave Mary a peach she ate it.

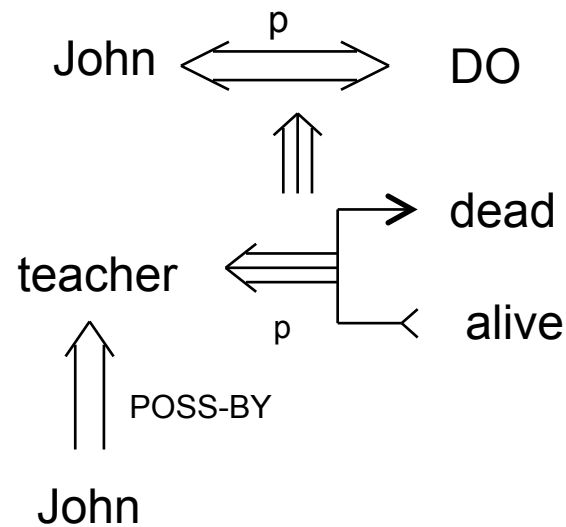


In the conceptualizations we are looking at there are events in which Actors execute some Acts



## State change "verbs"

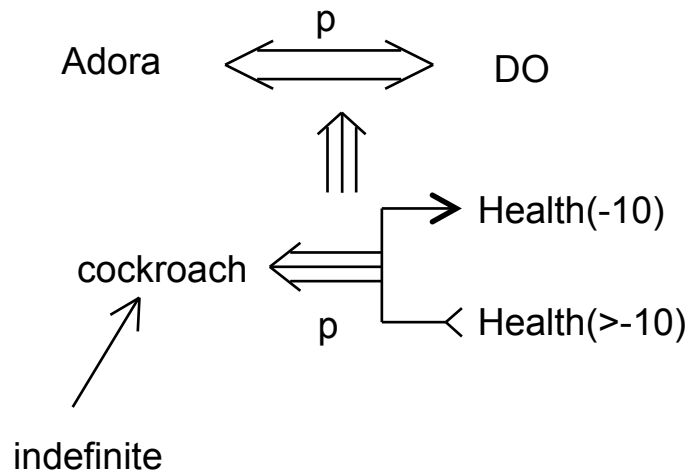
John killed his teacher.



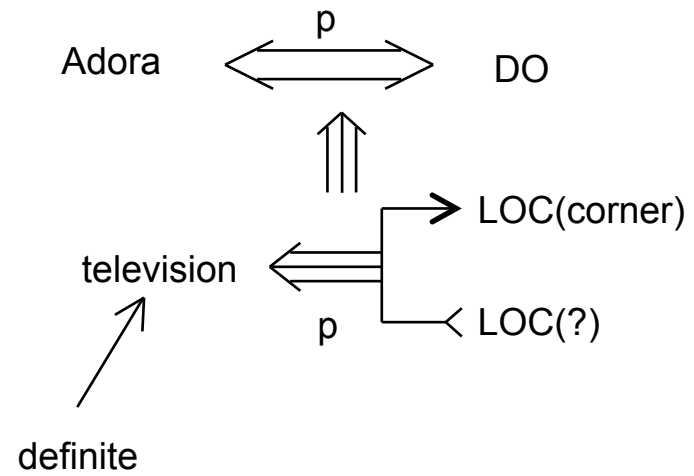
In state change verbs the linguistic verbs often focus on the state change while ignoring the action.

# State change "verbs"

Adora killed a cockroach

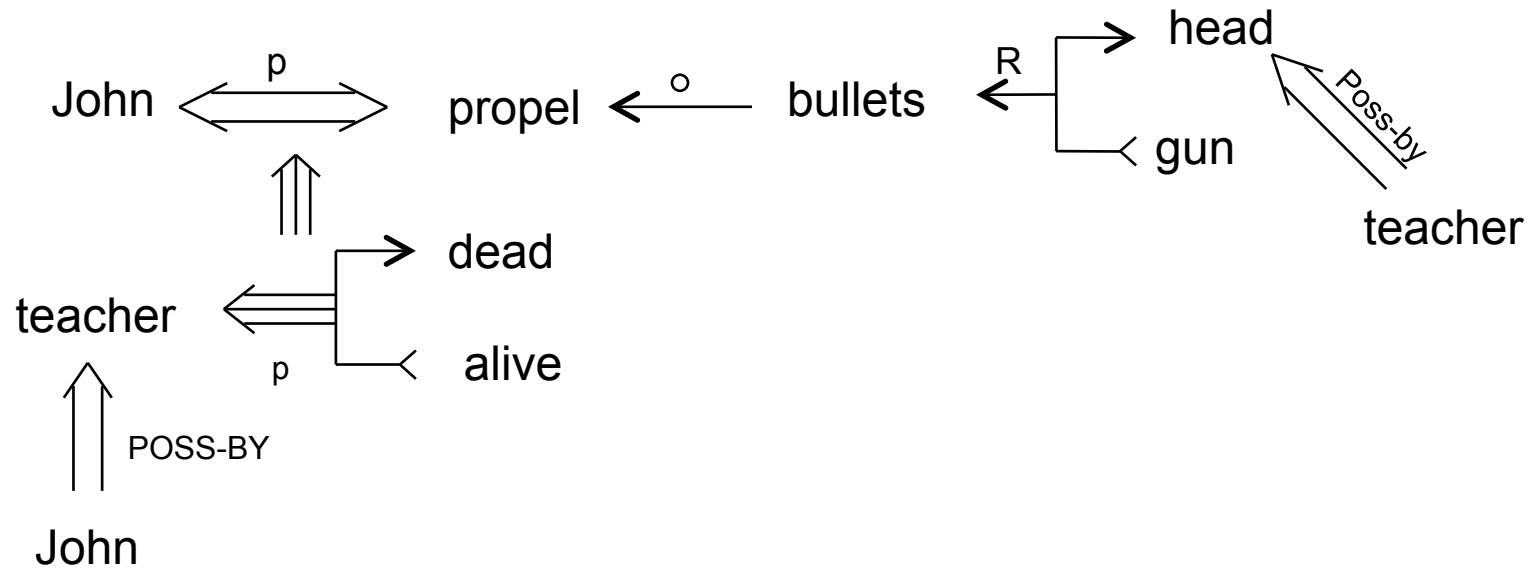


Adora moved the table to the corner



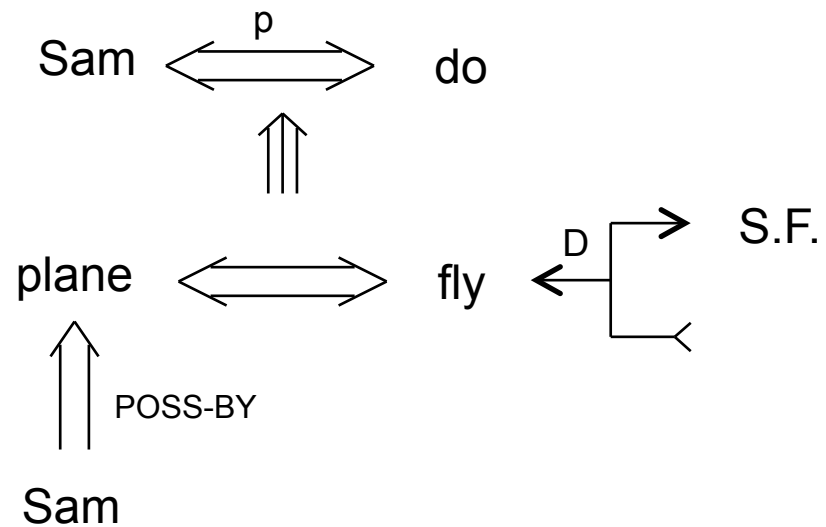
# Being more specific

John killed his teacher by shooting him in the head.



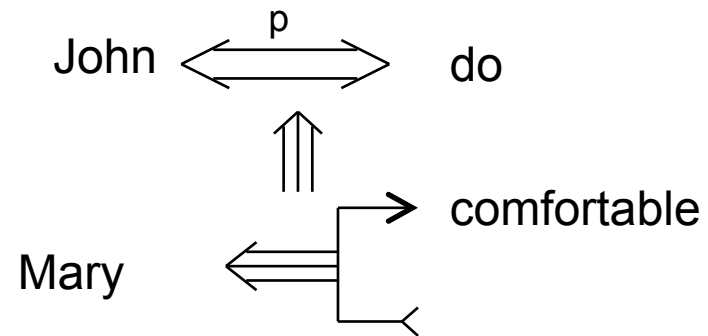
# Flying...

Sam flew his plane to San Francisco

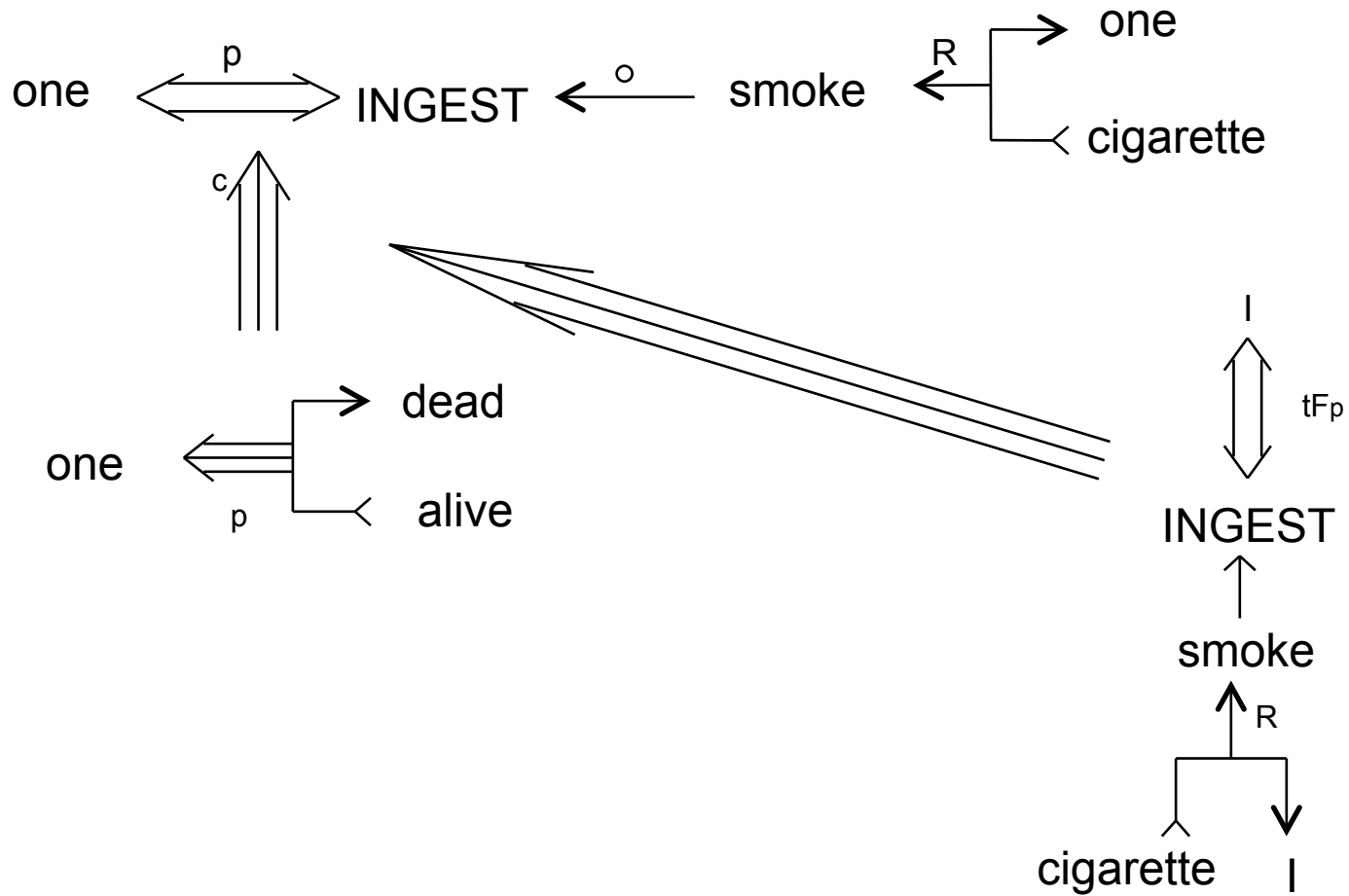


# Comforting

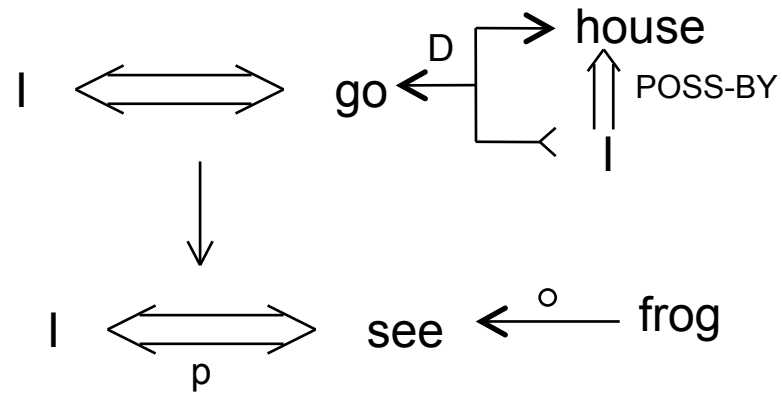
John comforted Mary



Since smoking can kill you, I stopped.



# While going home I saw a frog

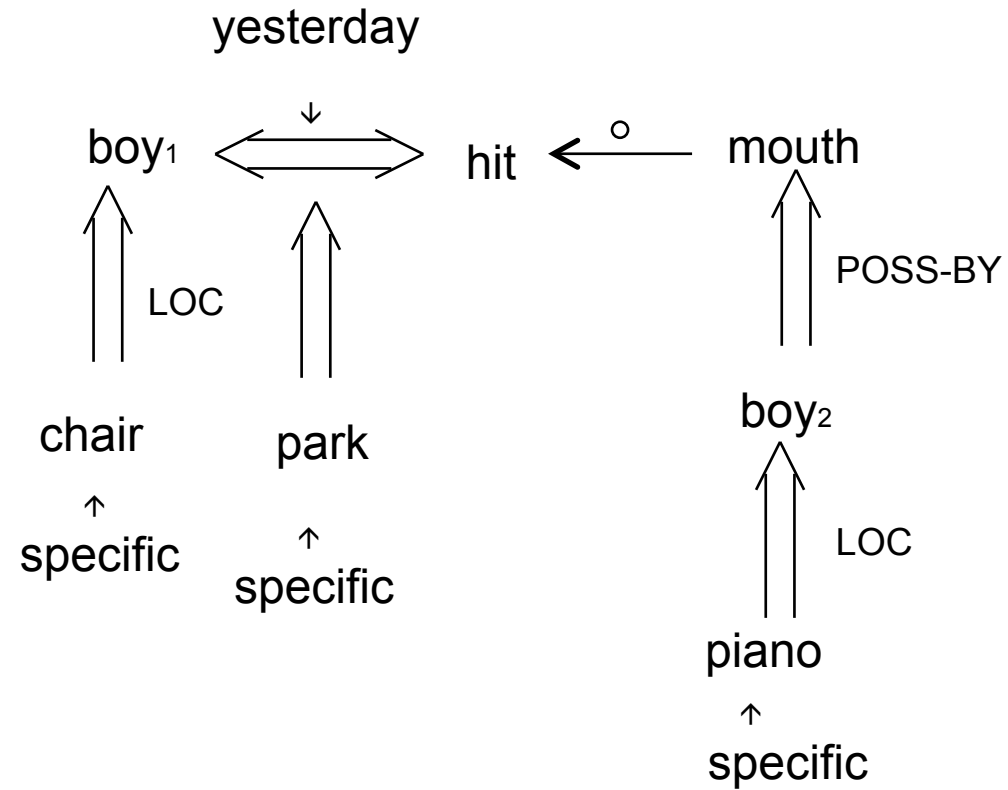


## Conceptual tenses

- P past
- f future
- t transition
- $t_s$  transition start
- $t_f$  transition finished
- k continuing
- ? Interrogative
- / negative
- c potential
- nil present
- $\Delta$  timeless



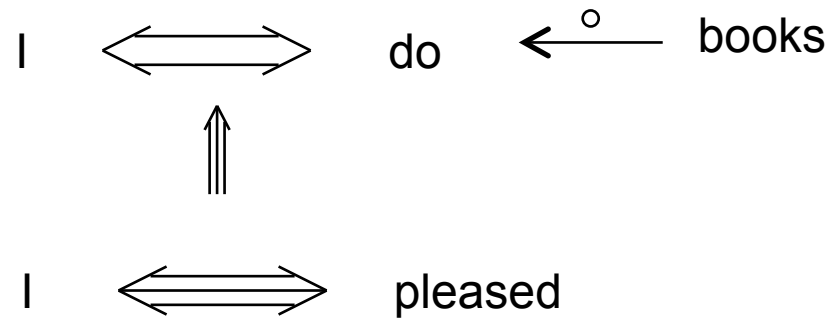
Yesterday, the boy in the chair hit the boy on the piano in the mouth in the park.



# Separating Action and State

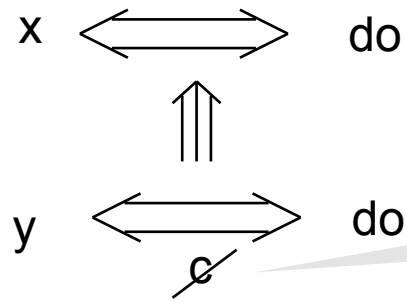
I like books

Books please me.



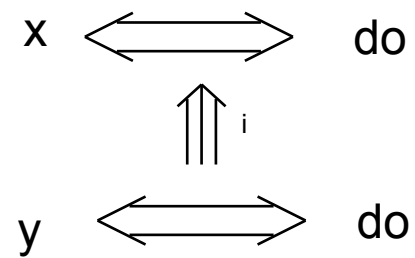
# Thinking actions

prevent



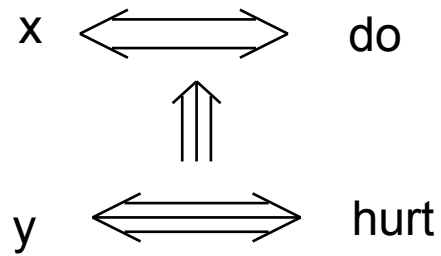
Cannot

instigate

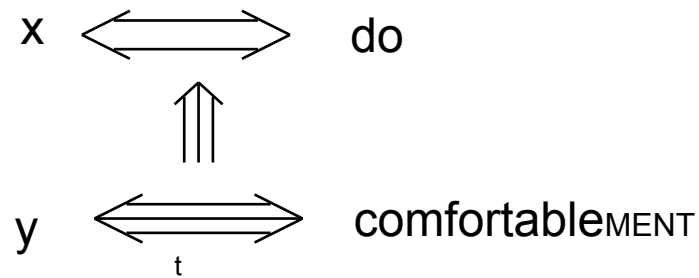


# Transitive verbs are causal relations

hurt

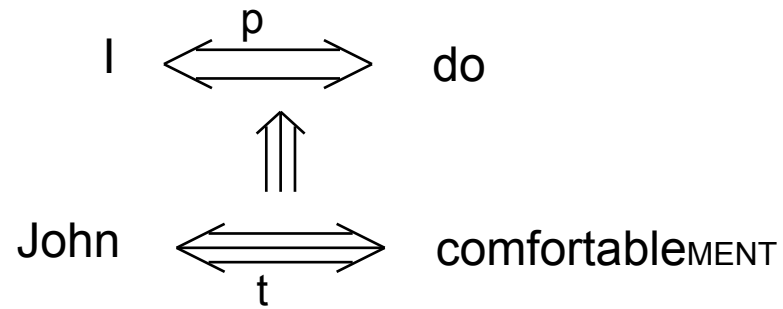


comfort



Mental state

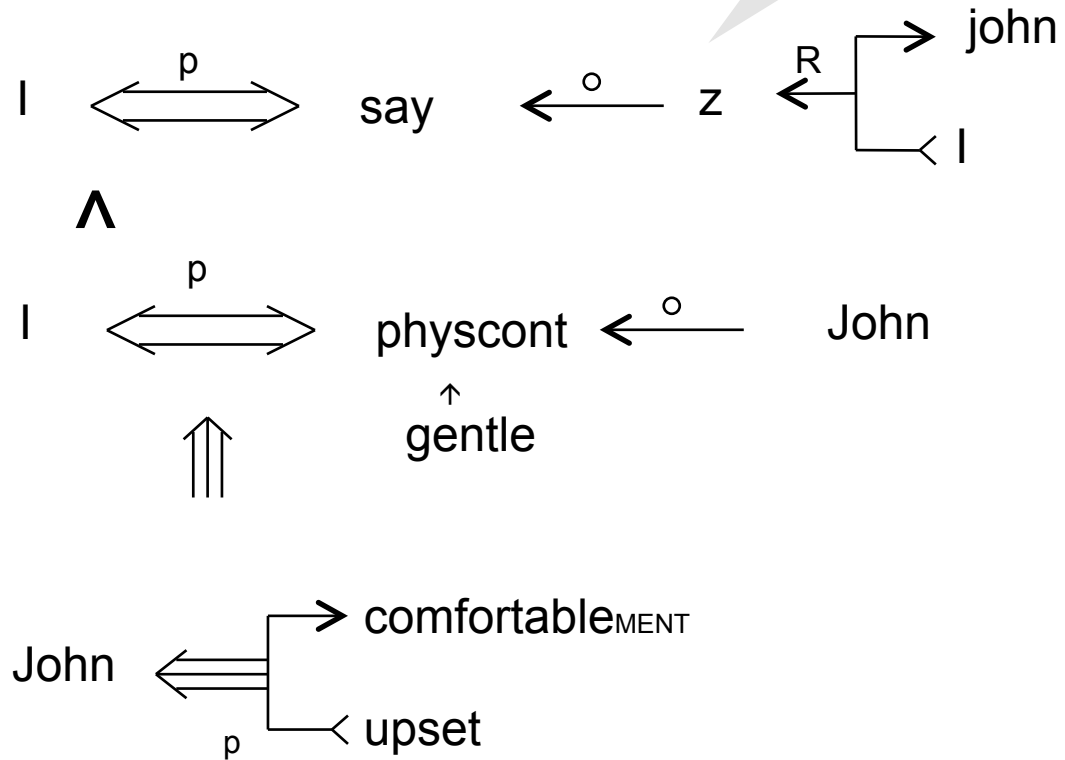
# I comforted John



# A more complete probabilistic analysis

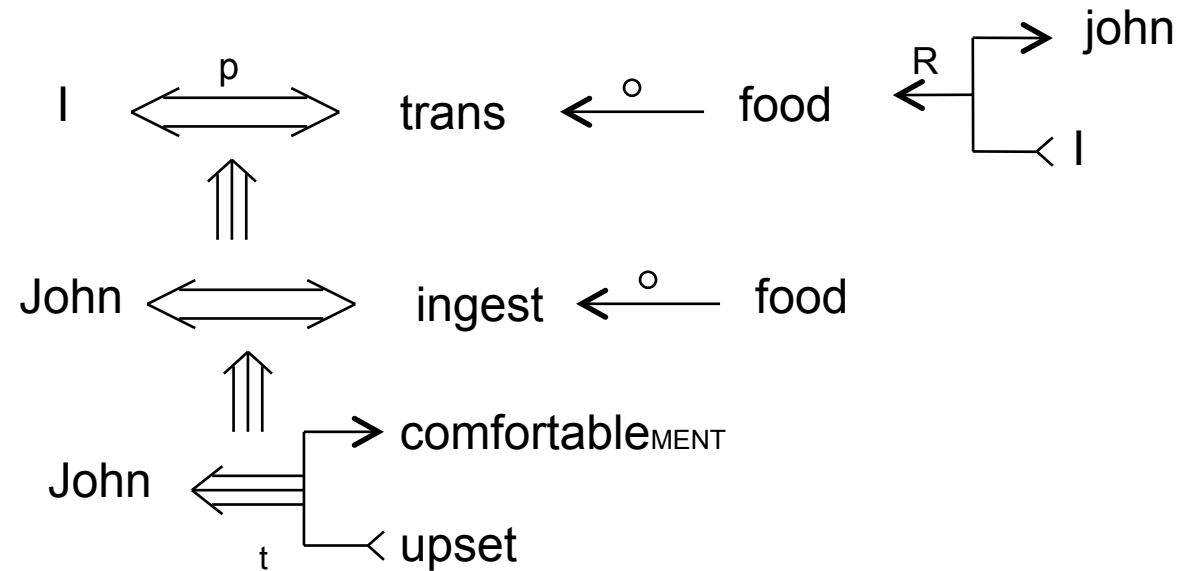
I comforted John

Soothing words?



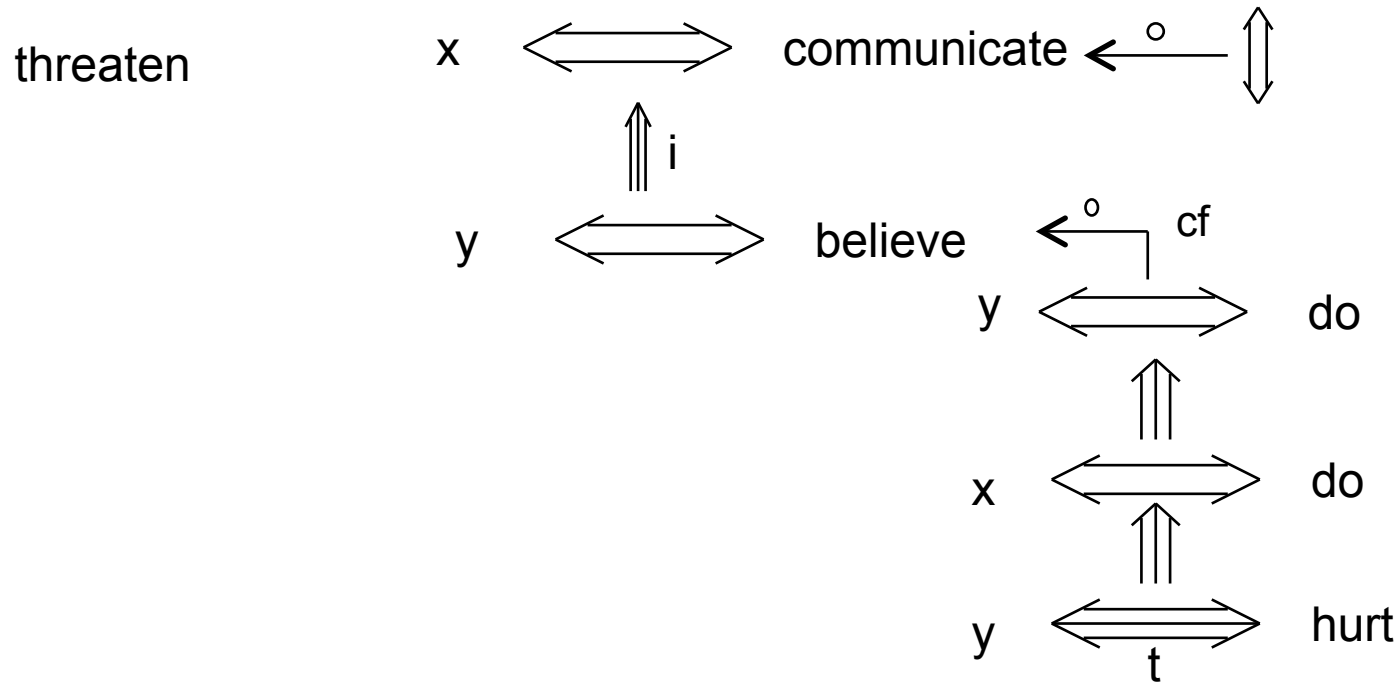
## A more specific sentence...

I comforted John by feeding him.



Note : Giving food *leads to* eating food *leads to* becoming comfortable

# A general threat

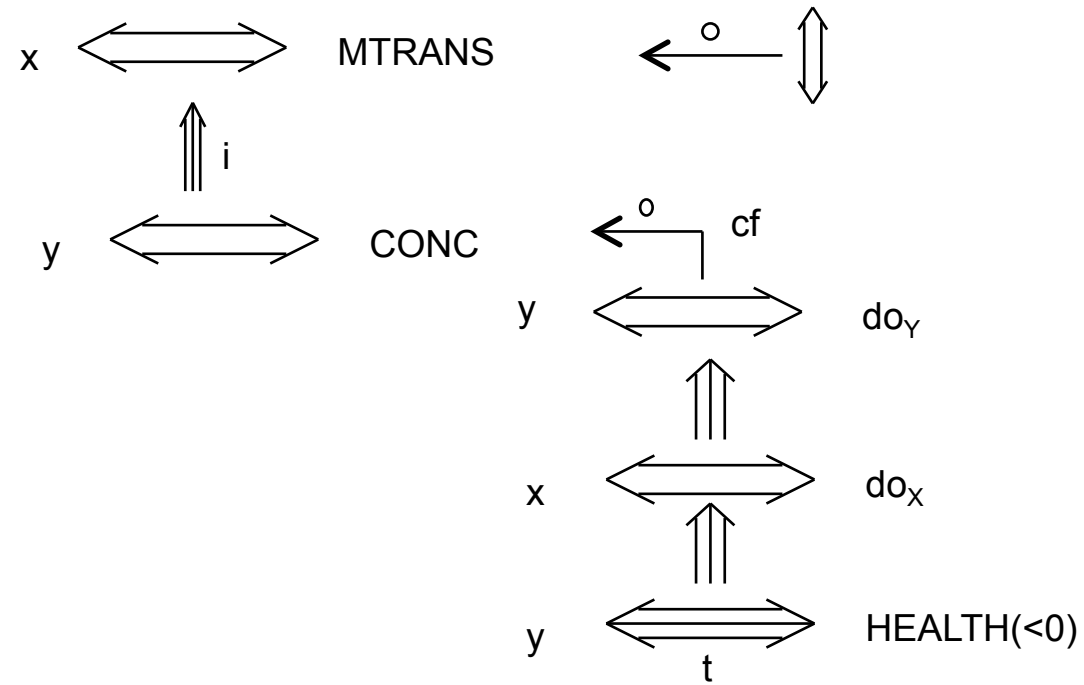


Note : Y comes to BELIEVE that if Y does something ... it is modeled as Y in fact getting threatened.



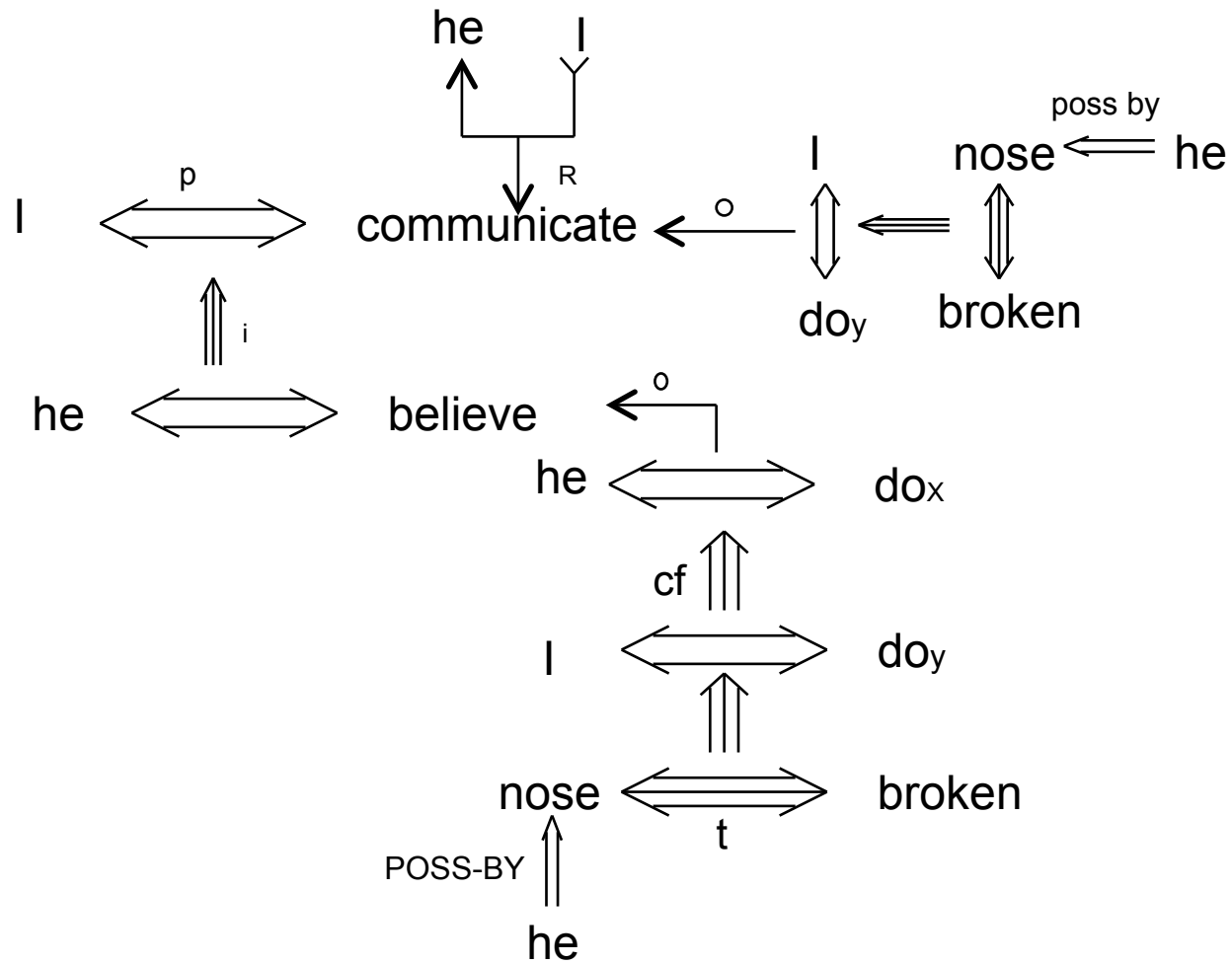
# A general threat

threaten



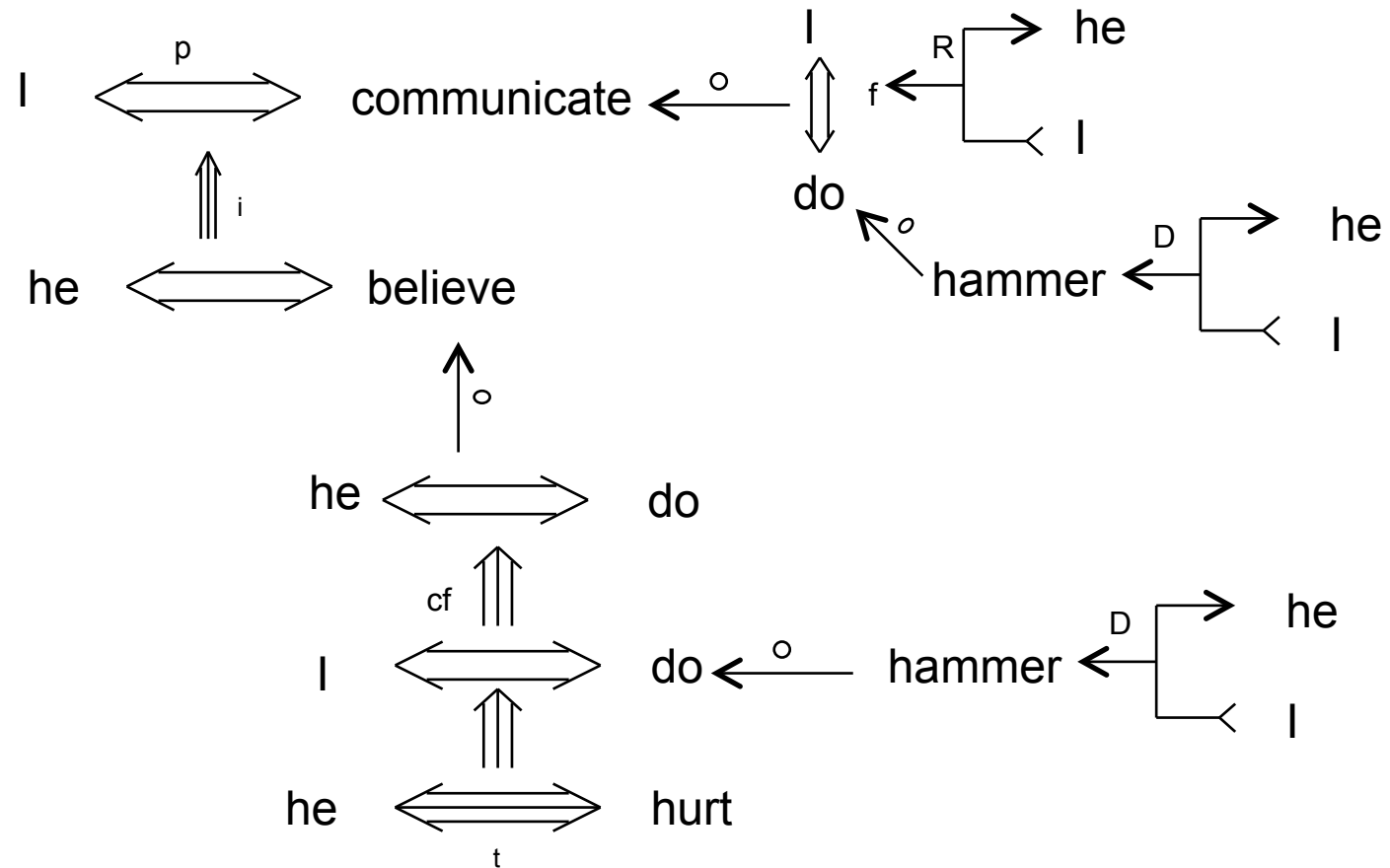
# A specific threat

I threatened him with a broken nose



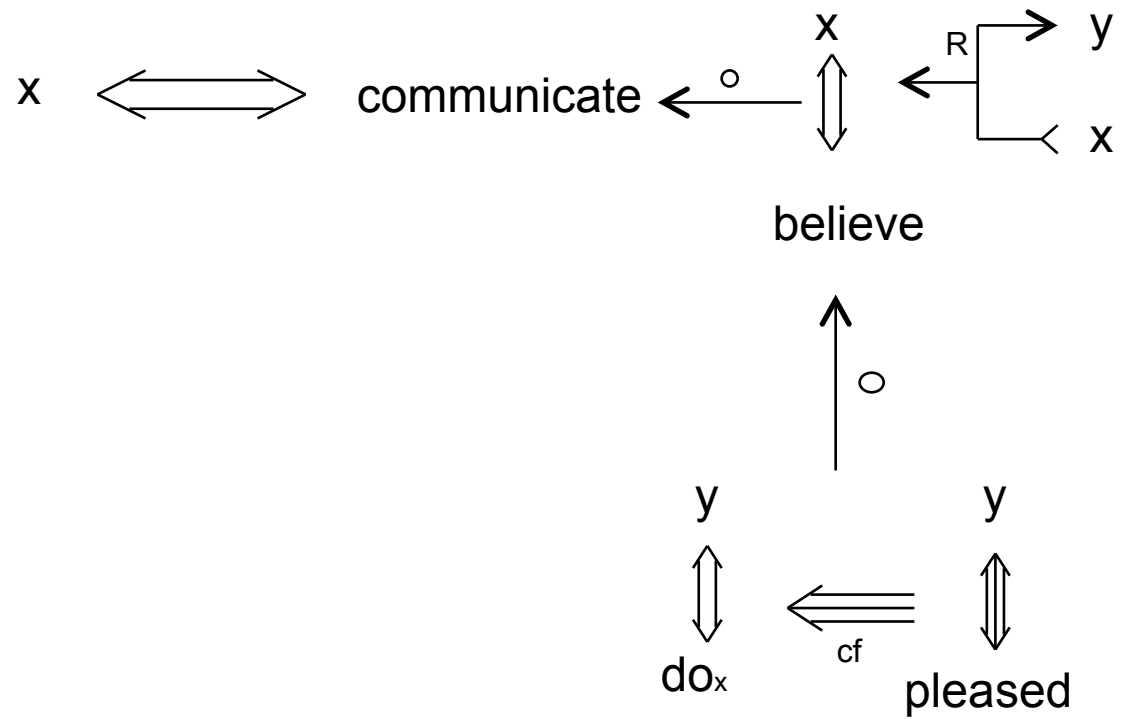
# Another explicit threat

I threatened him with a hammer.



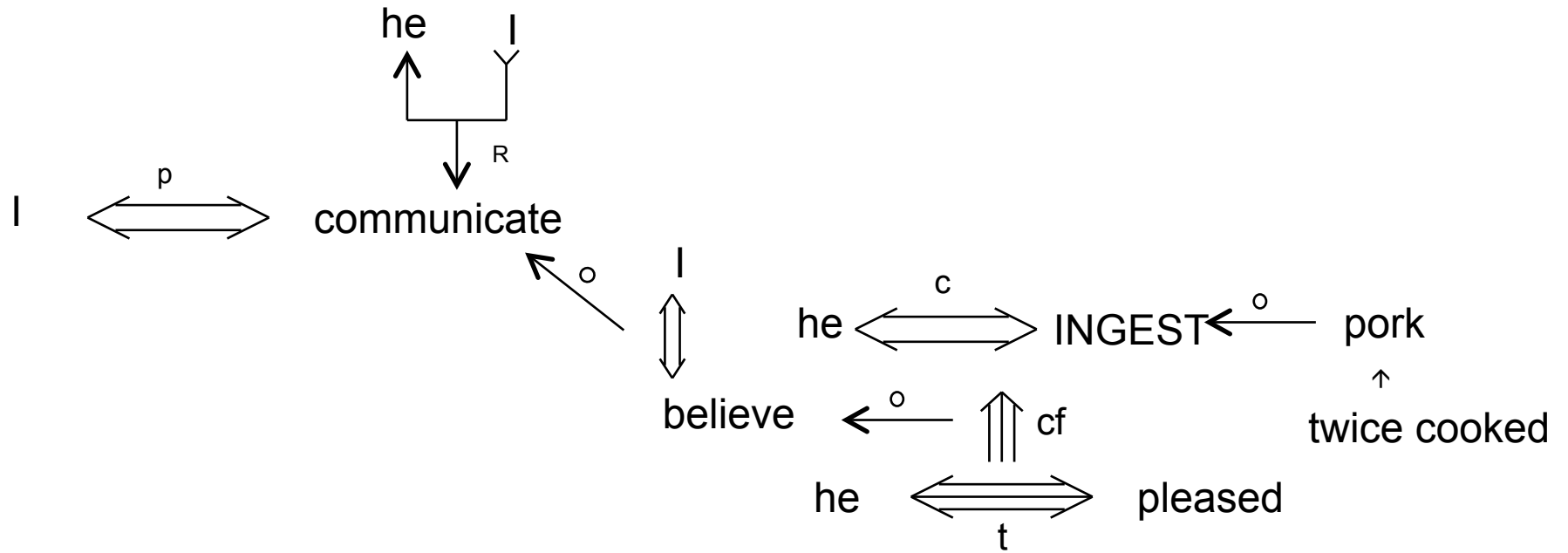
# Advise communicates belief of speaker

advise

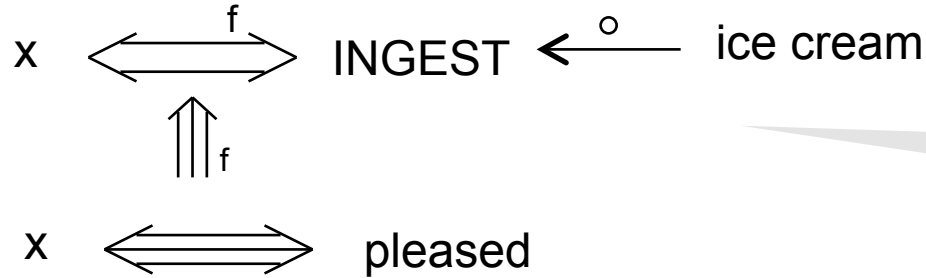


# Some eating advise

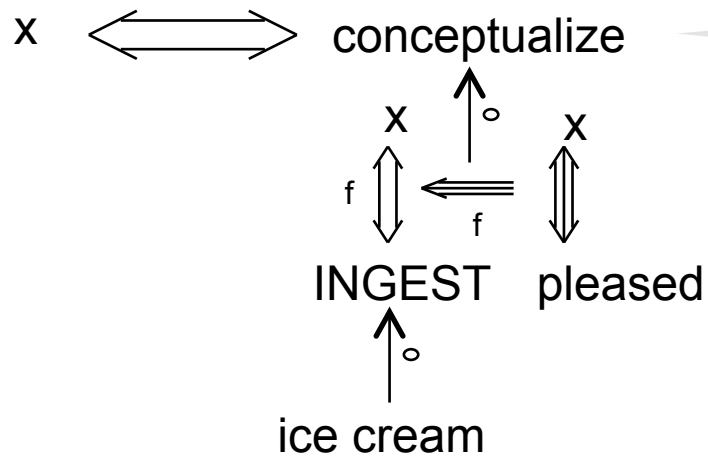
I advised him to try the twice cooked pork



# Liking ice cream

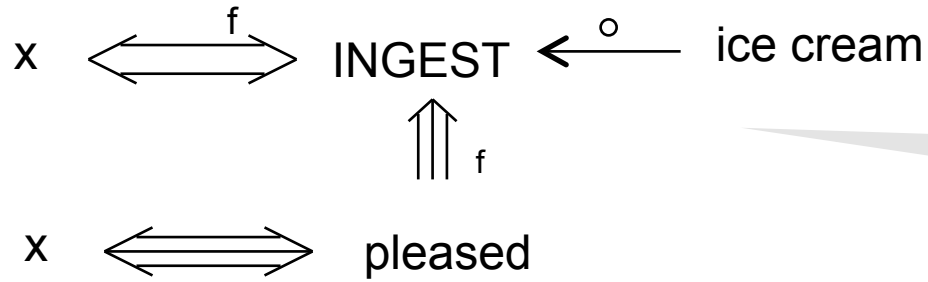


No thought component!

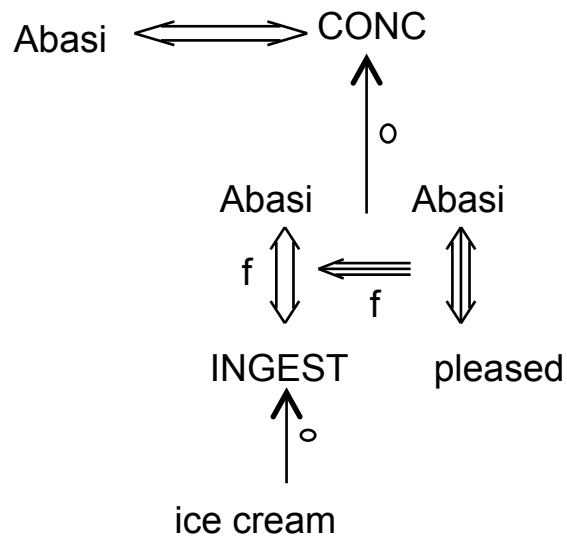


X thinks that X will be pleased if X eats ice cream

# Liking ice cream



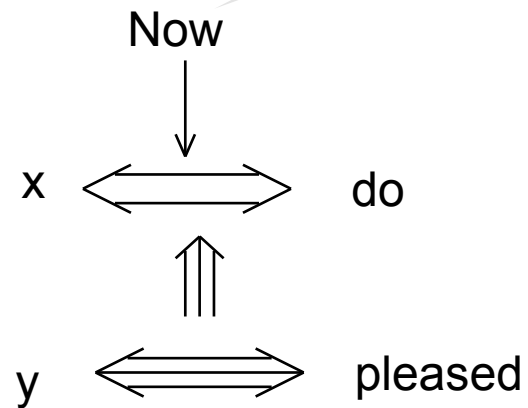
No thought component!



## Want has a specific time sense

want

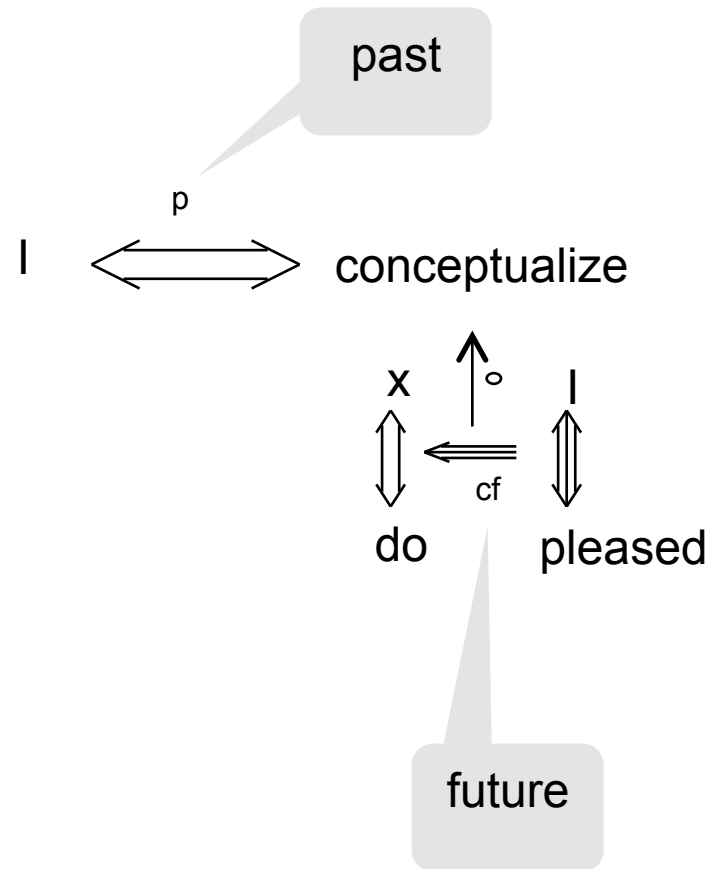
For example





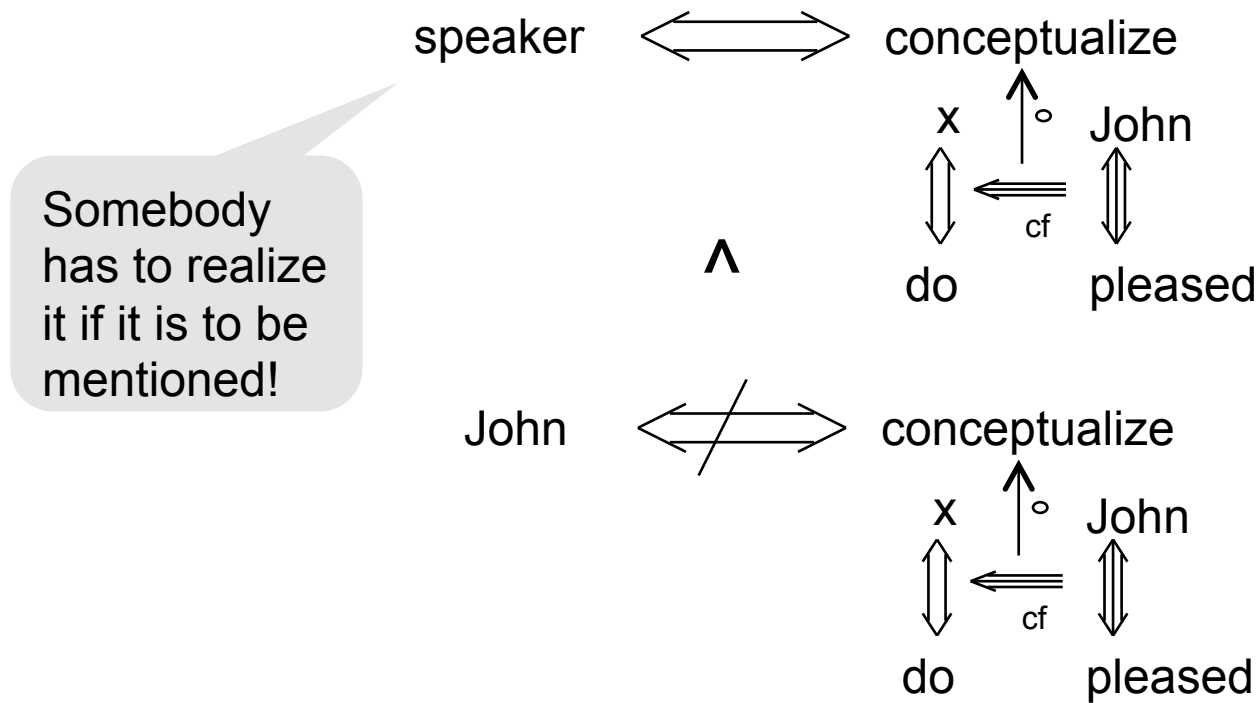
# Past and future

I wanted it



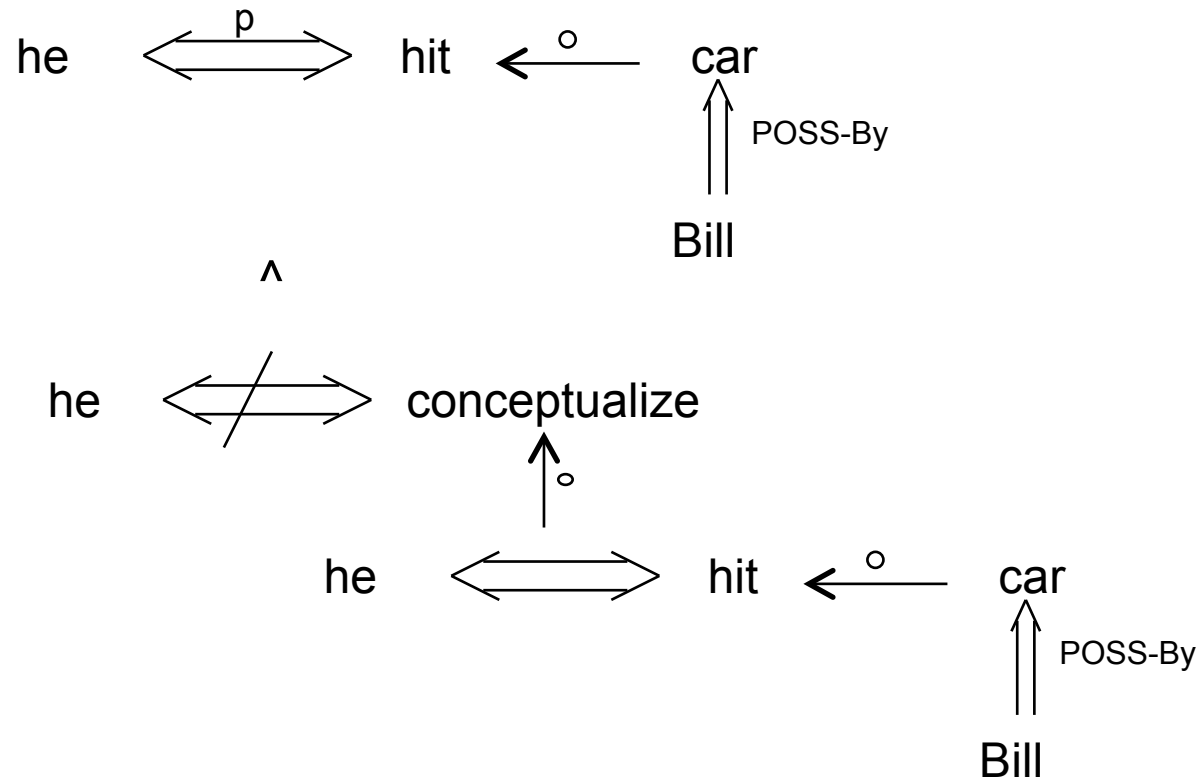
# realization

John wants it but he doesn't realize it



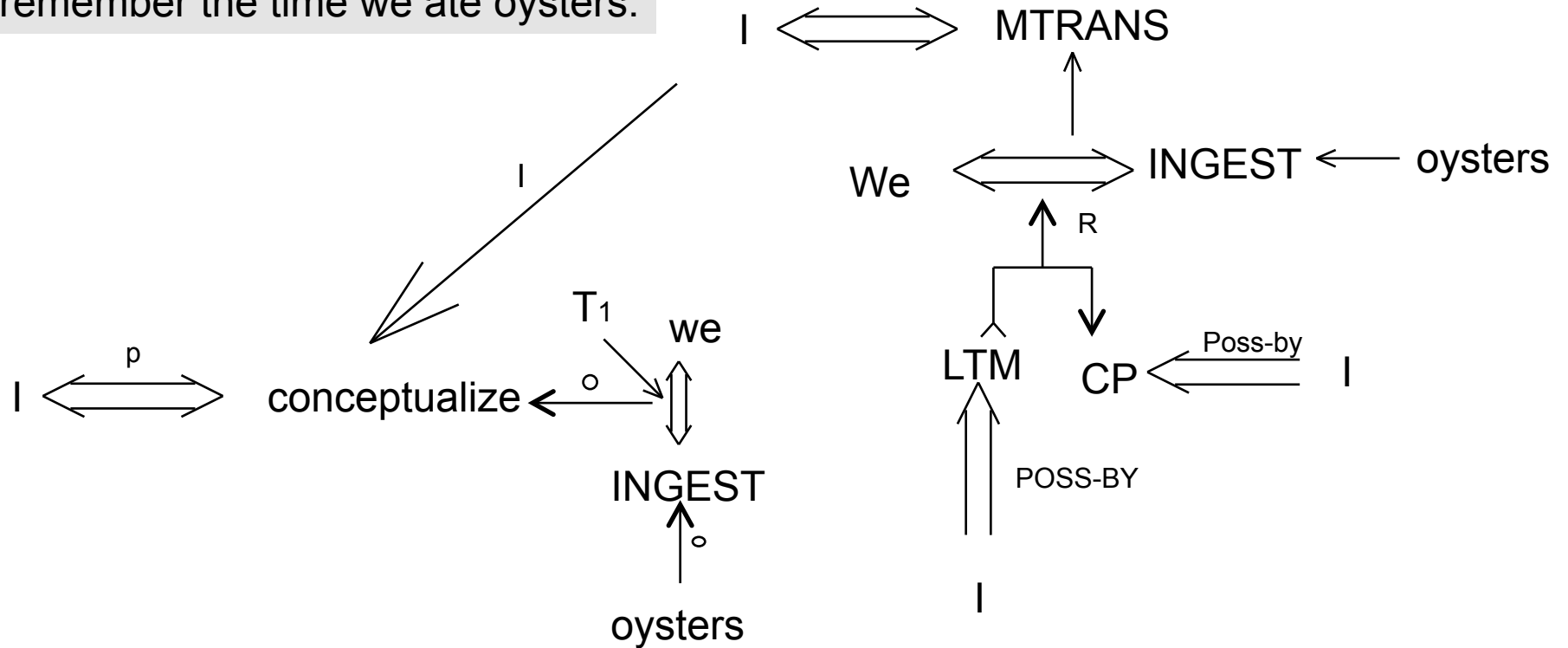
# Unawareness

He hit Bill's car but he doesn't know it.



# Remembering is thinking about

I remember the time we ate oysters.



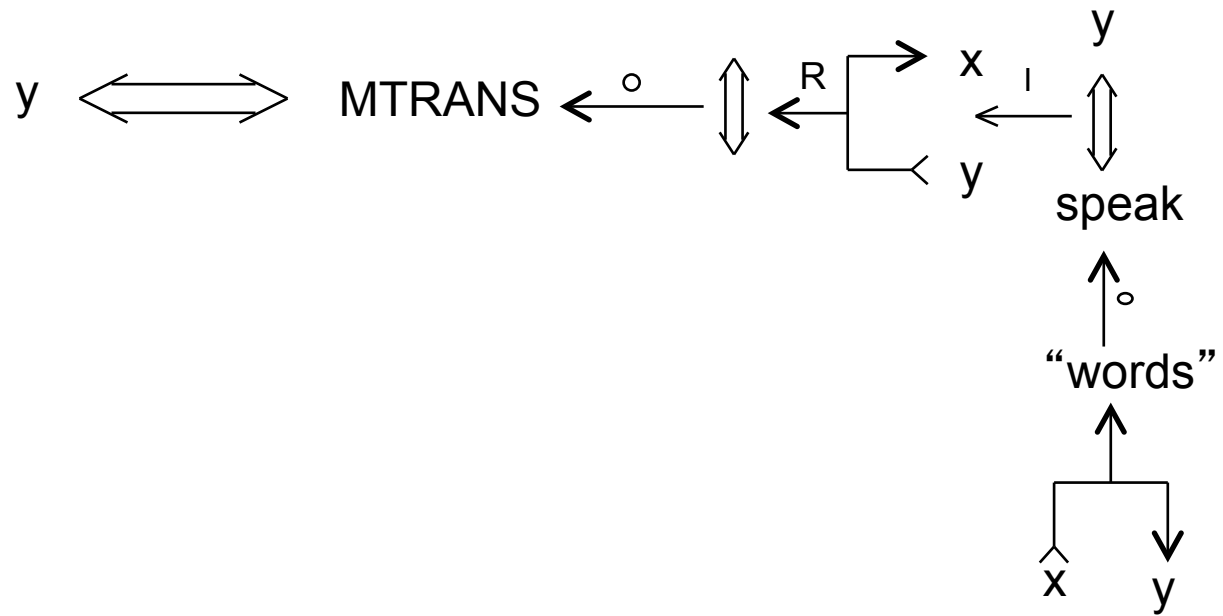
Remembering BY Mtransing it from LTM to CP (conscious processor)

# MTRANS – transferring info - "mental"

communicate

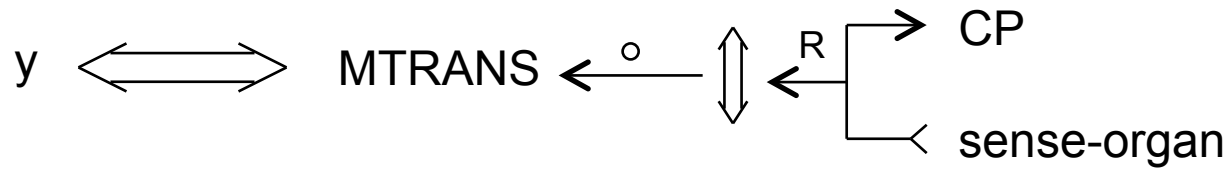


say to / tell

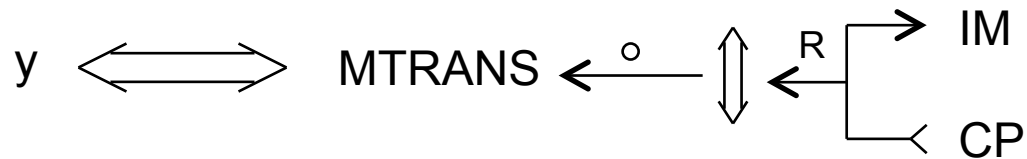


# Movement of info within

Perceive



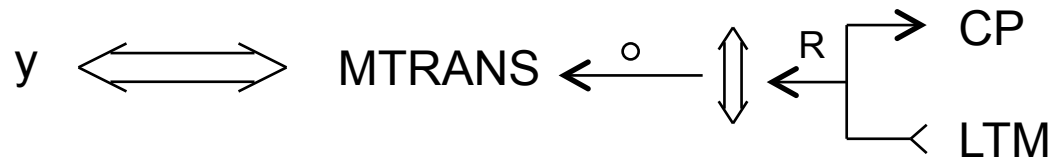
Learn



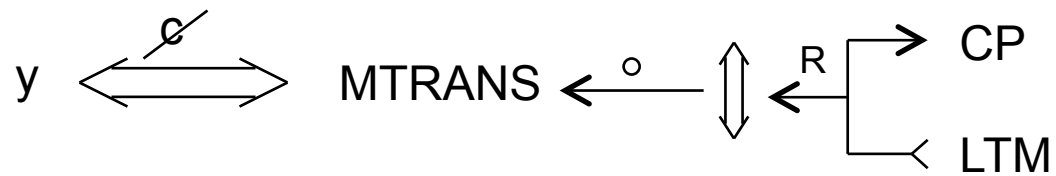
Immediate  
Memory

# Forgetting is being unable to remember

remember

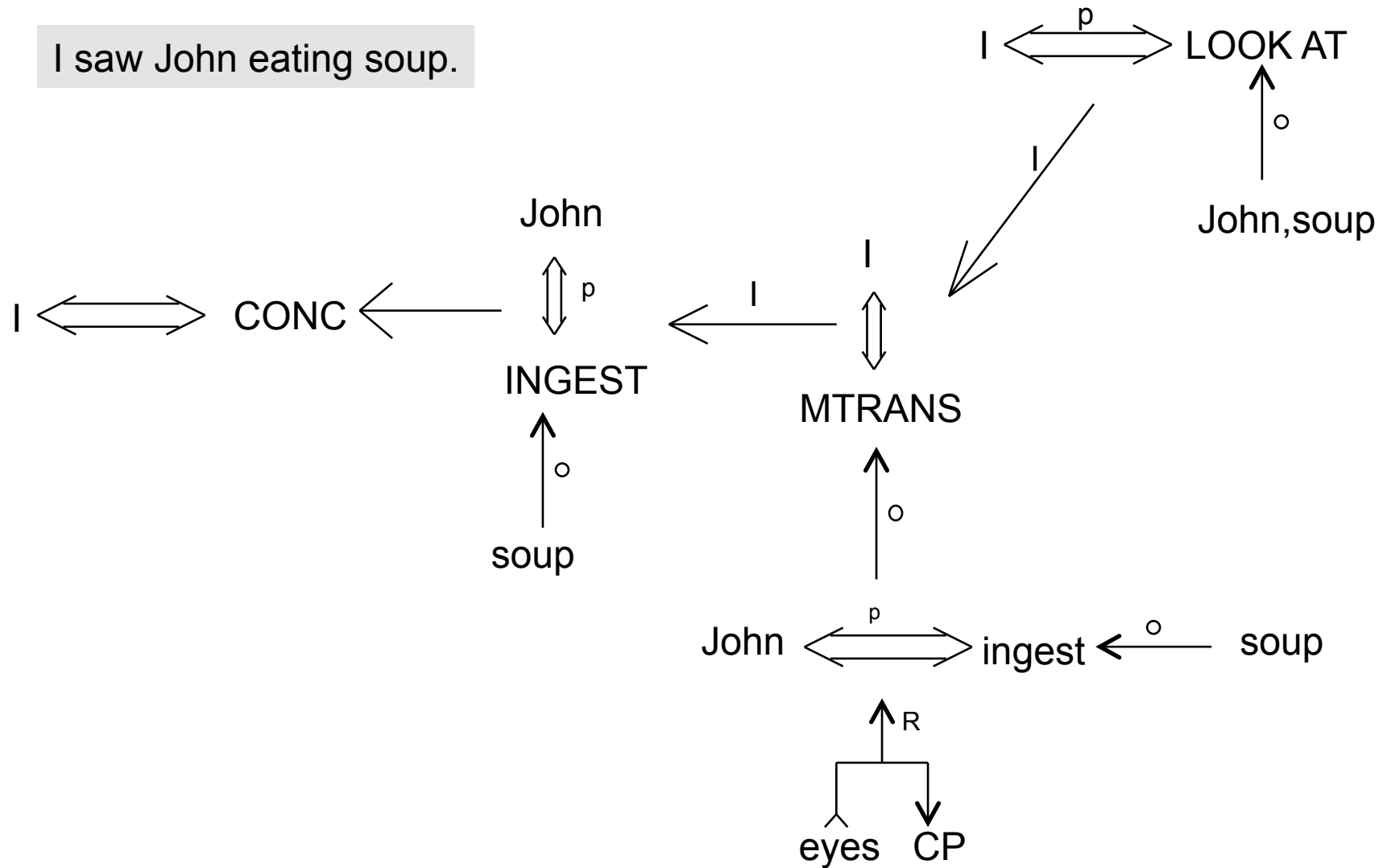


forget



# Seeing as conceptualizing

I saw John eating soup.





# To Conceptualize is to Ponder

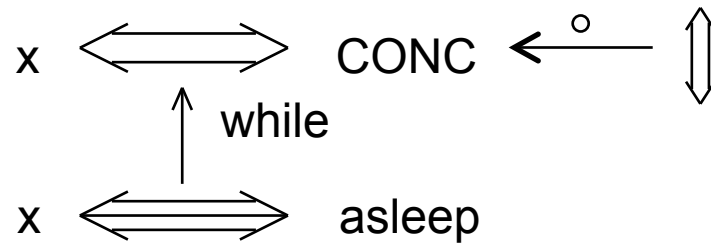
consider



ponder



dream

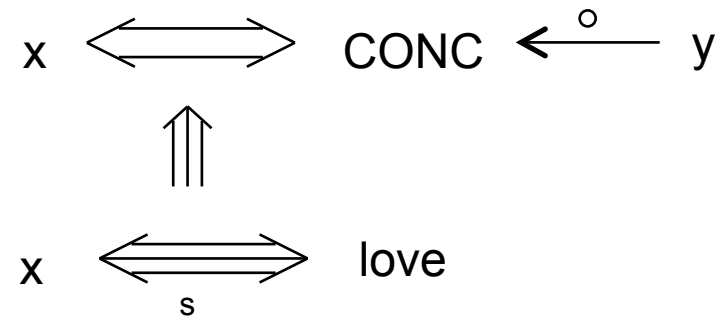


wonder

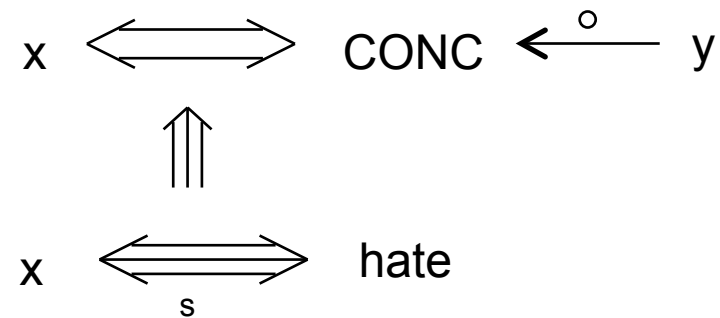


# Love and hate are states

love



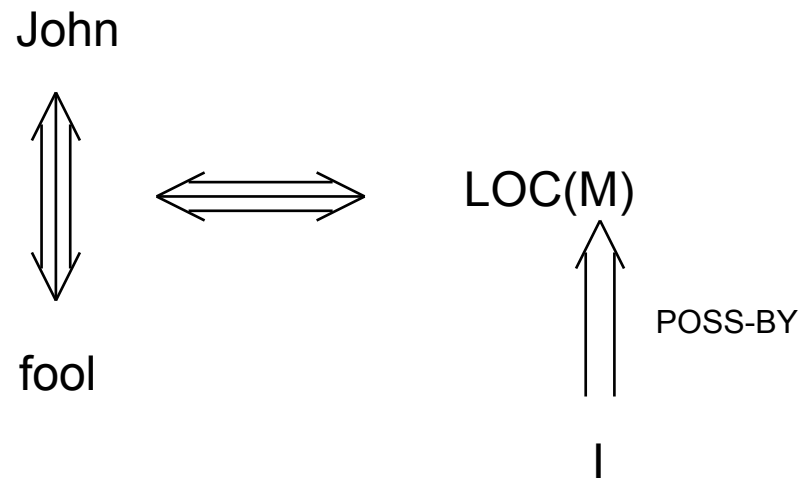
hate



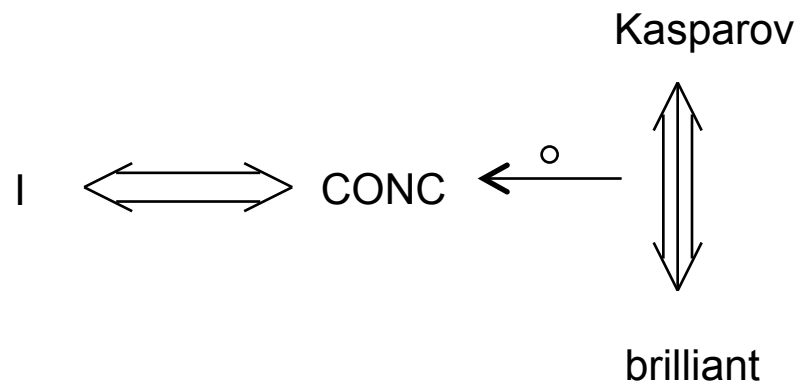
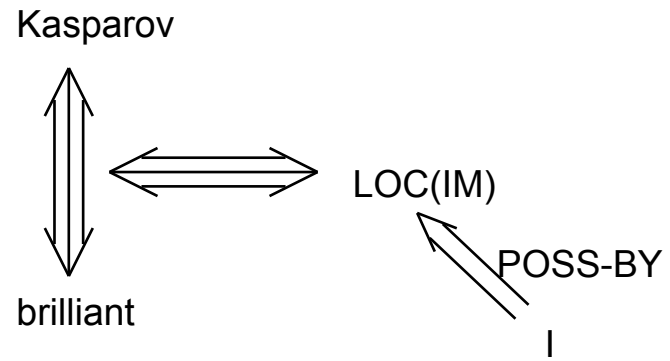
## Think – another sense

I believe that John is a fool

I think that John is a fool

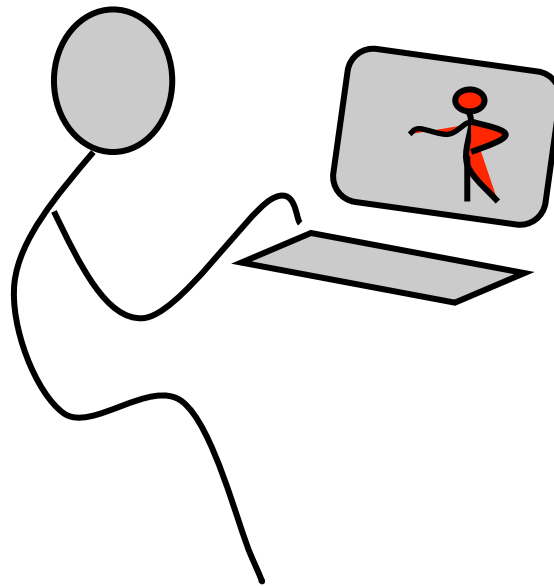


The conceptualization "John is a fool" is located in my memory.



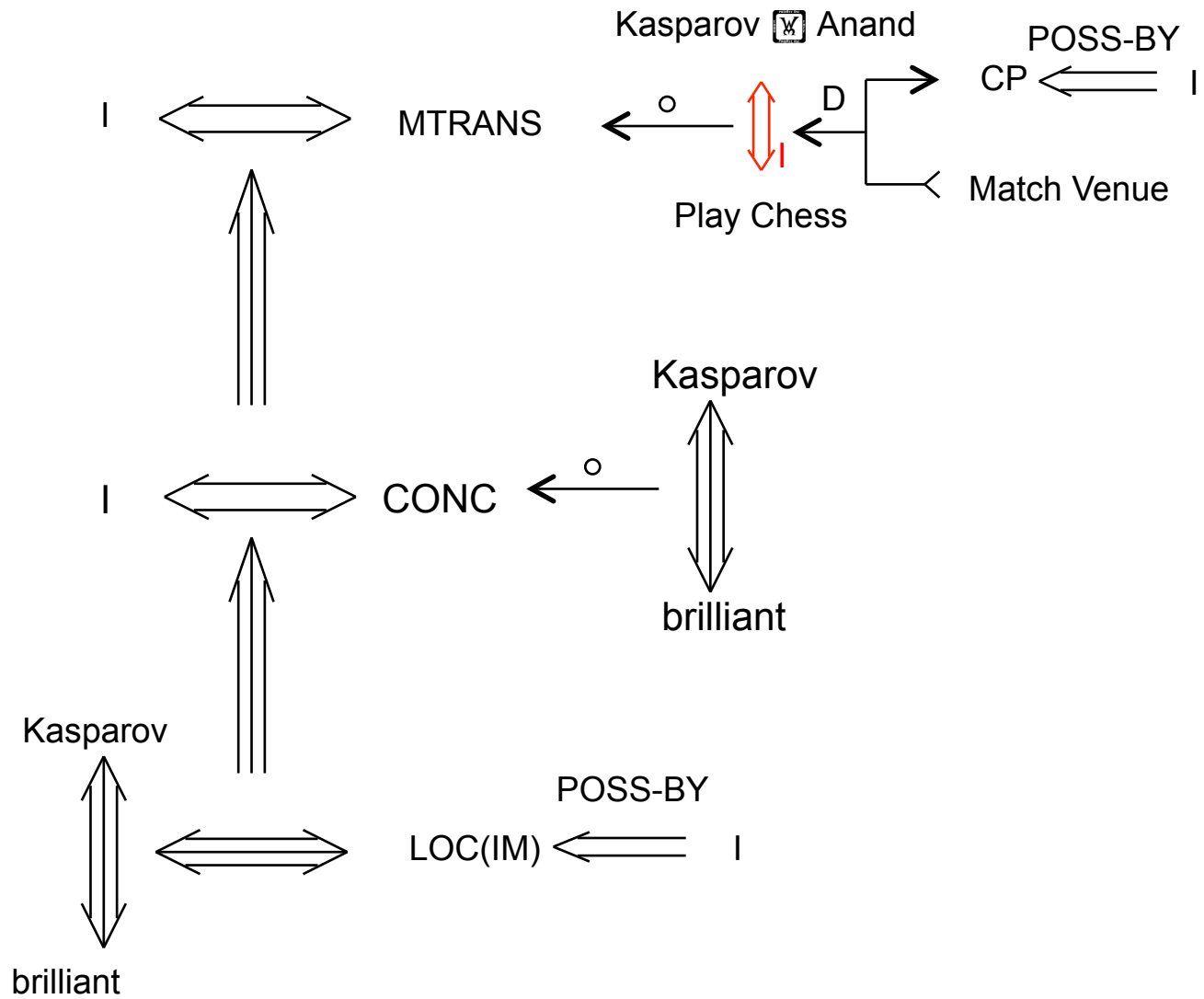
## ACTIONS: Inputs to Understanding

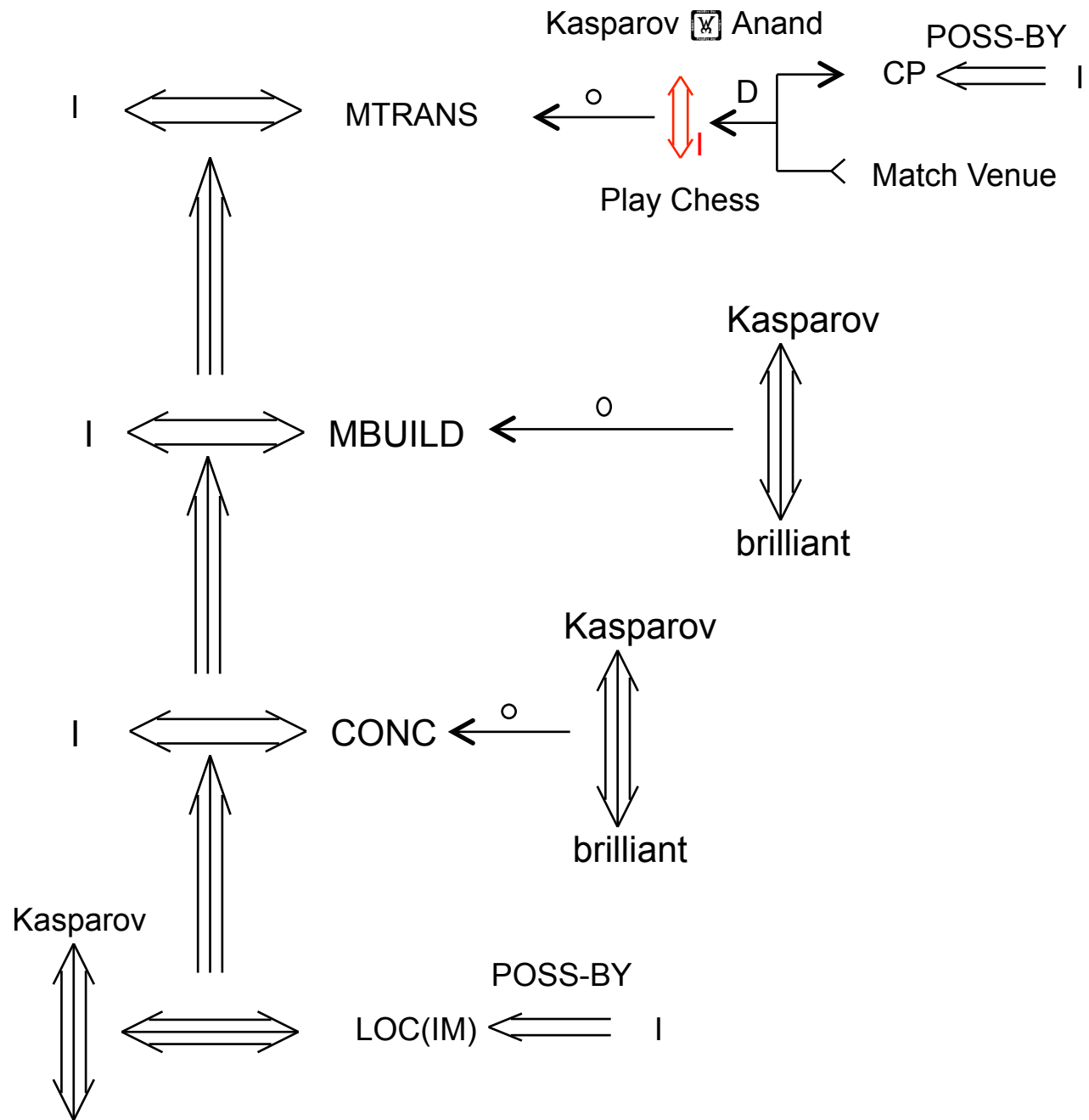
- Goals and Plans are *not* linguistic entities
- Instead they form Knowledge Structures
- Goals and Plans are often not stated explicitly
- Instead what we see is a sequence of Actions
- For example, designing a game playing agent :



For an intelligent game agent, actions are your keyboard strokes... it needs to understand your intentions from them.

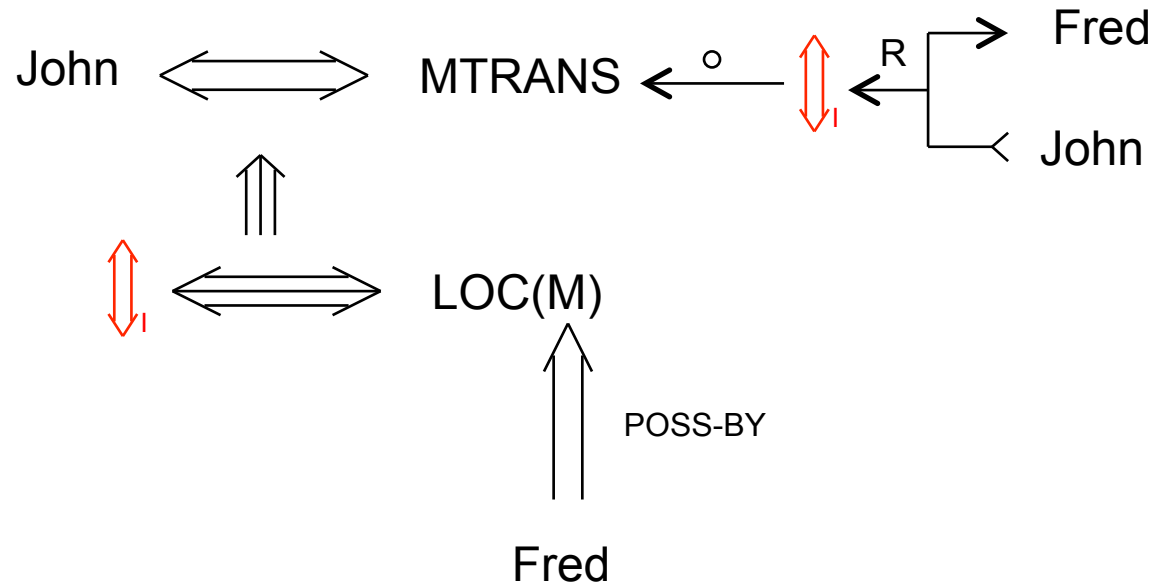
Software agents have to make sense of information coming via the keyboard or some other medium.





# Believes

Fred believes John.

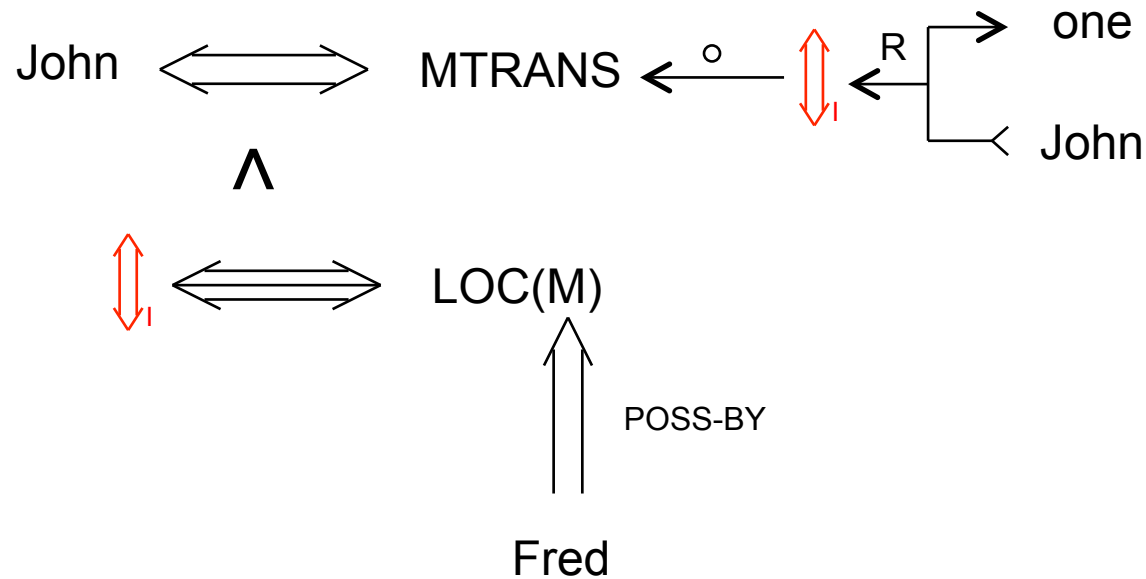


Fred tells something to John, and John puts it in his memory.



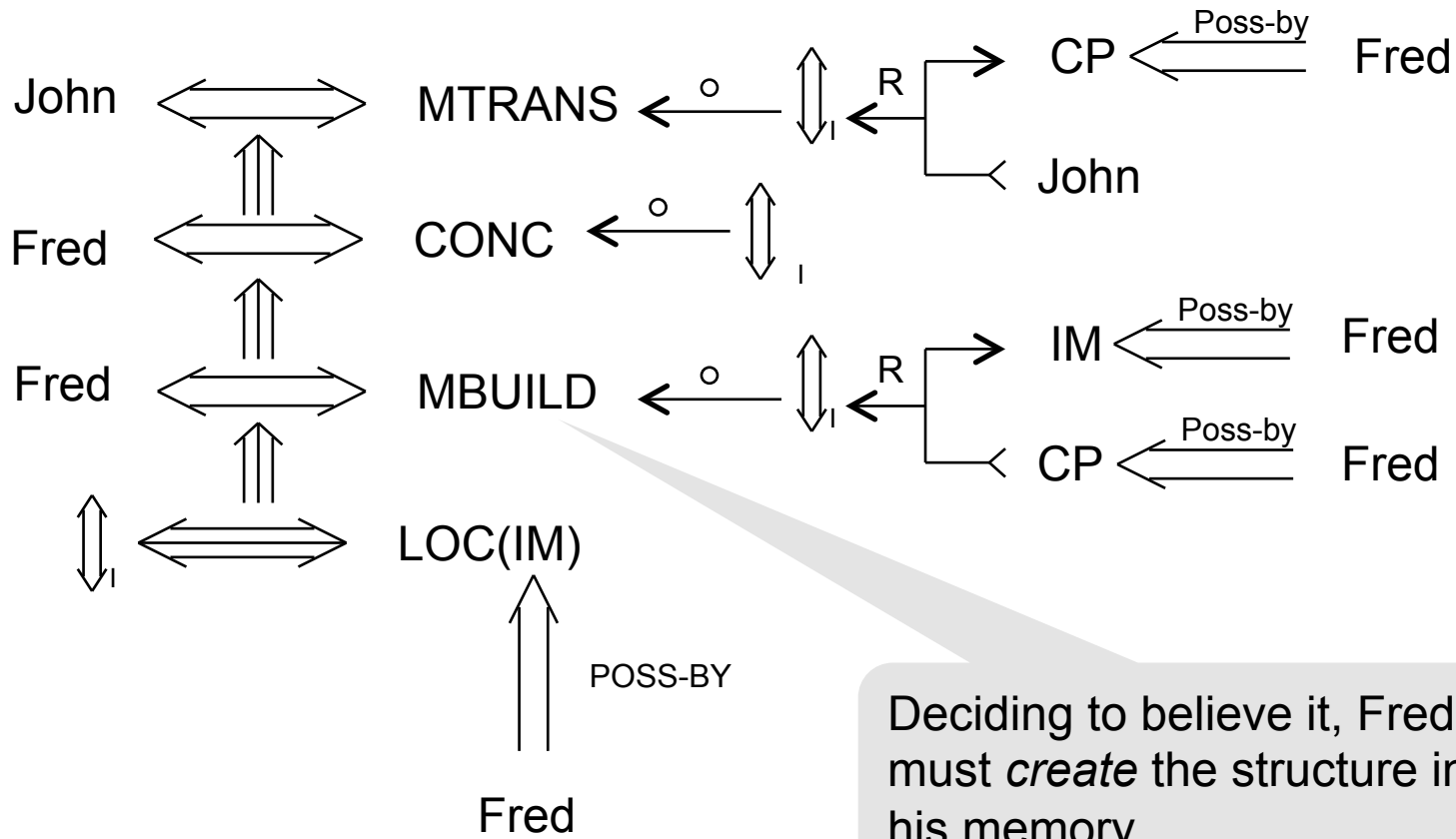
# Believes – as in agrees with

Fred believes John.



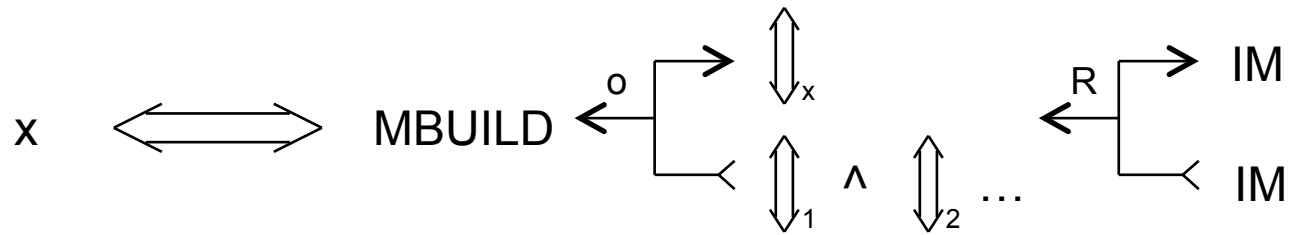
John is saying something (to someone) and Fred also believes that.

# But Fred must "put" it in his memory



# Modeling inferences

Conclude – infer  $F_x$  from  $F_1, F_2, \dots$



## Physical actions in CD

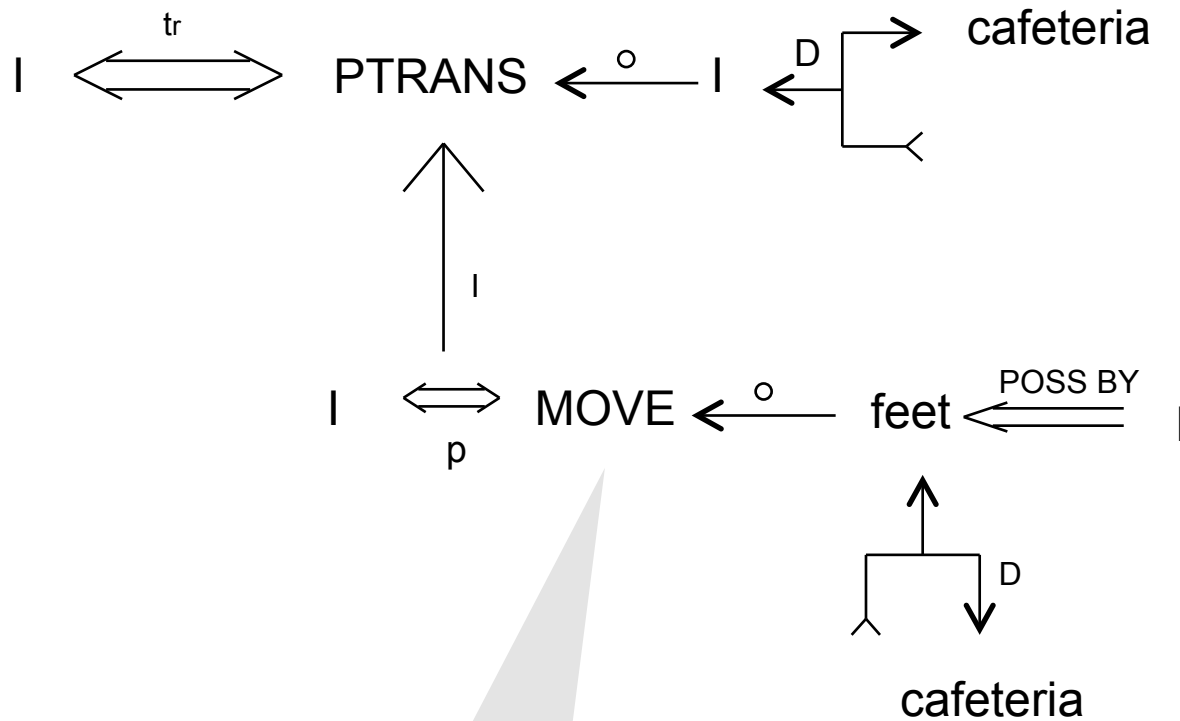
MOVE	own body part
PROPEL	something else
INGEST	input
EXPEL	output
PTRANS	change of location
GRASP	grasp

If a PTRANS happens then infer that (1) the object ceases to be at the origin location and (2) exists at destination location.

Likewise in ATRANS, but *not* in MTRANS  
(except when donor is CP)

# I walked to the cafeteria

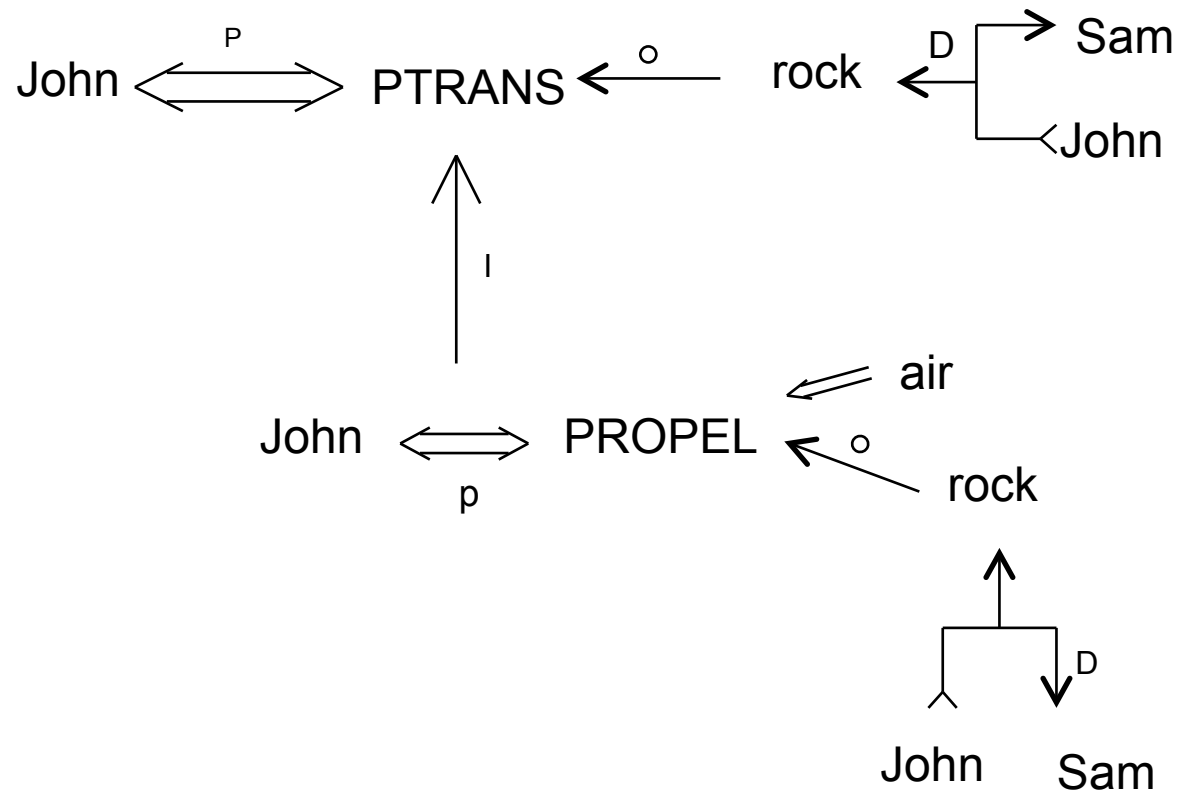
The key act is PTRANS. Infer that I am at cafeteria



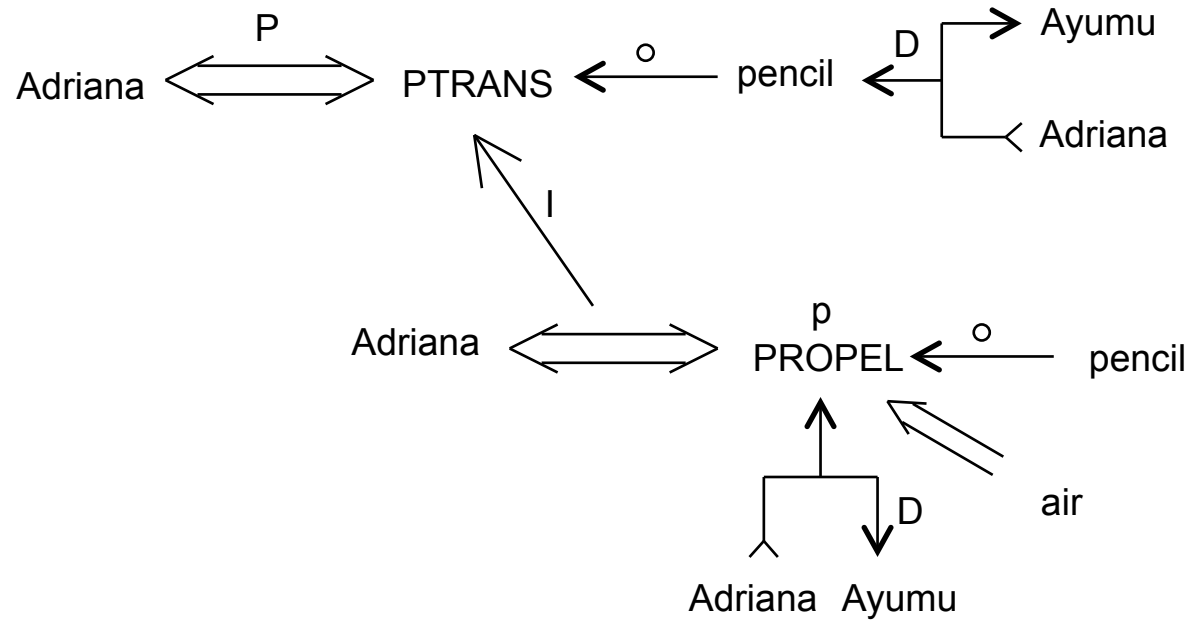
MOVE is instrumental act

# John threw a rock at Sam

Throw = PTRANS in air by doing PROPEL

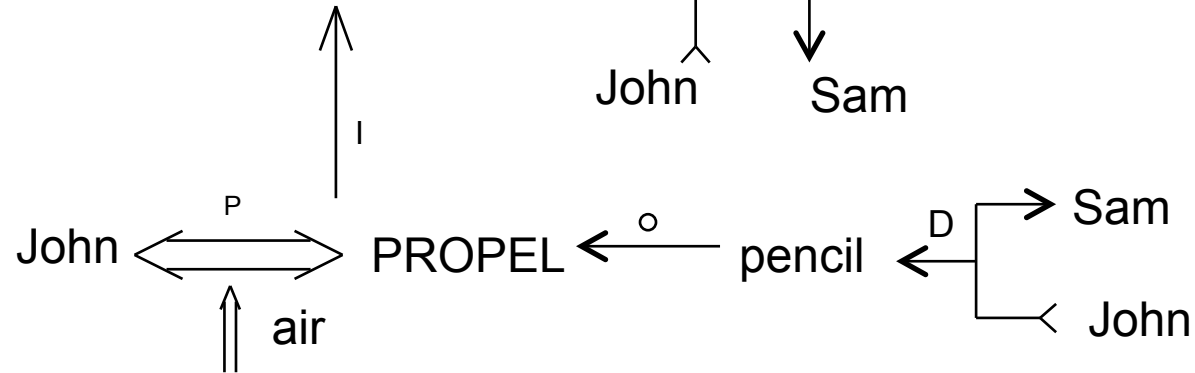
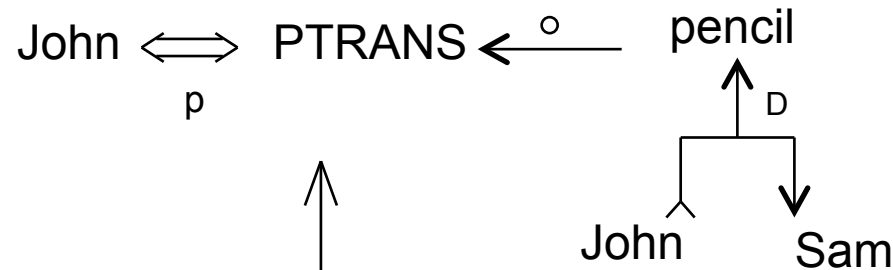
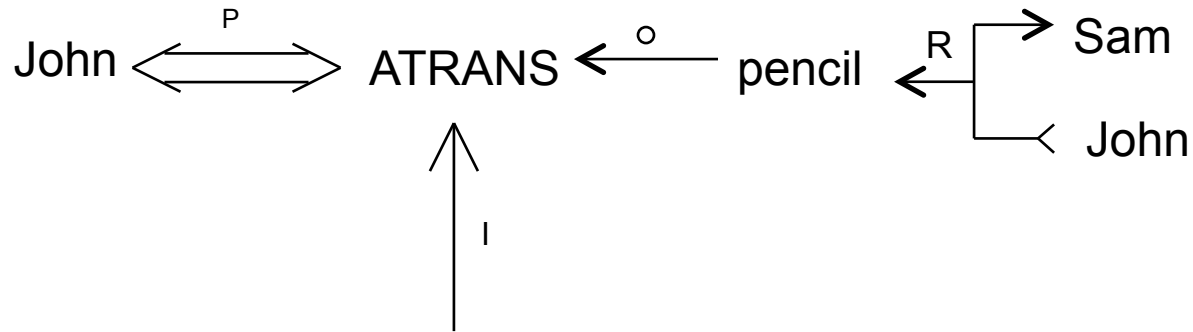


# John threw a rock at Sam



# John threw the pencil to Sam.

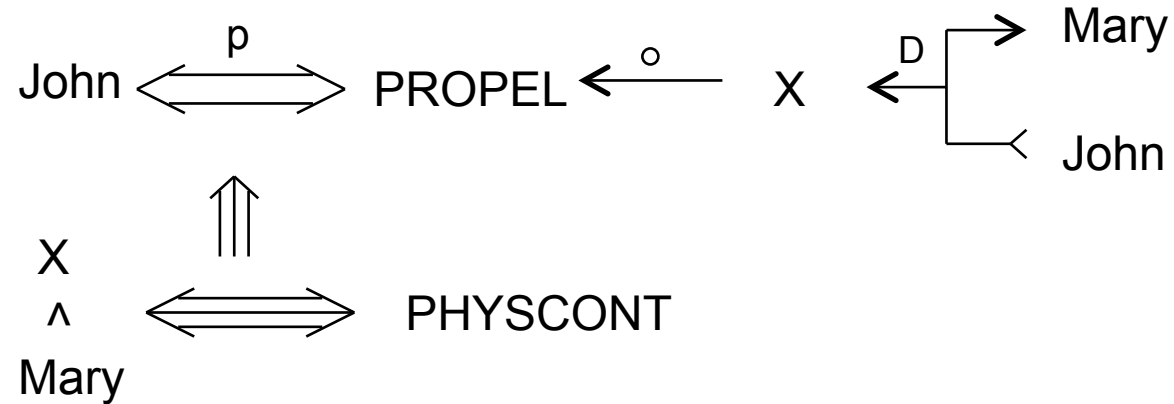
Throw to – is an instrumental act for ATRANS



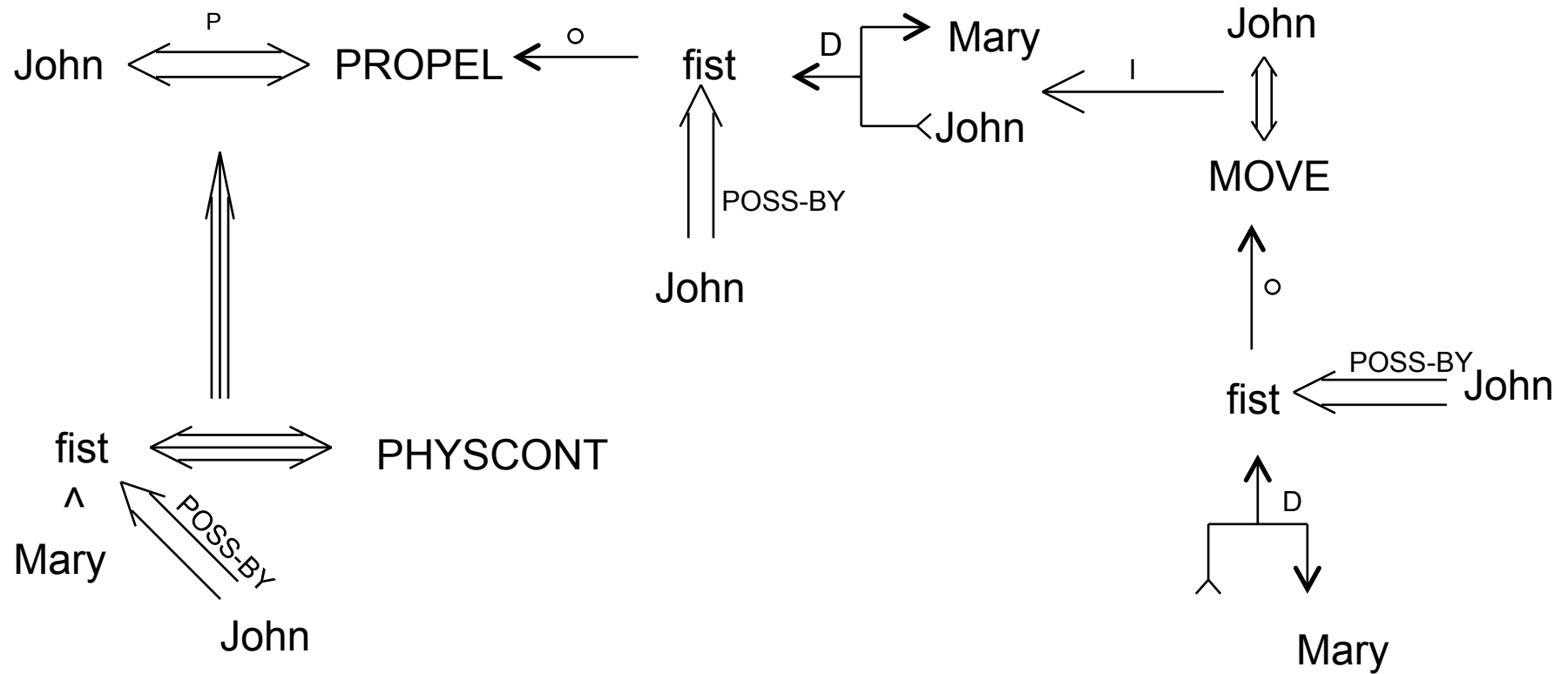


# John hit Mary

Hit with something. PROPEL that something so that it comes into (hard) contact

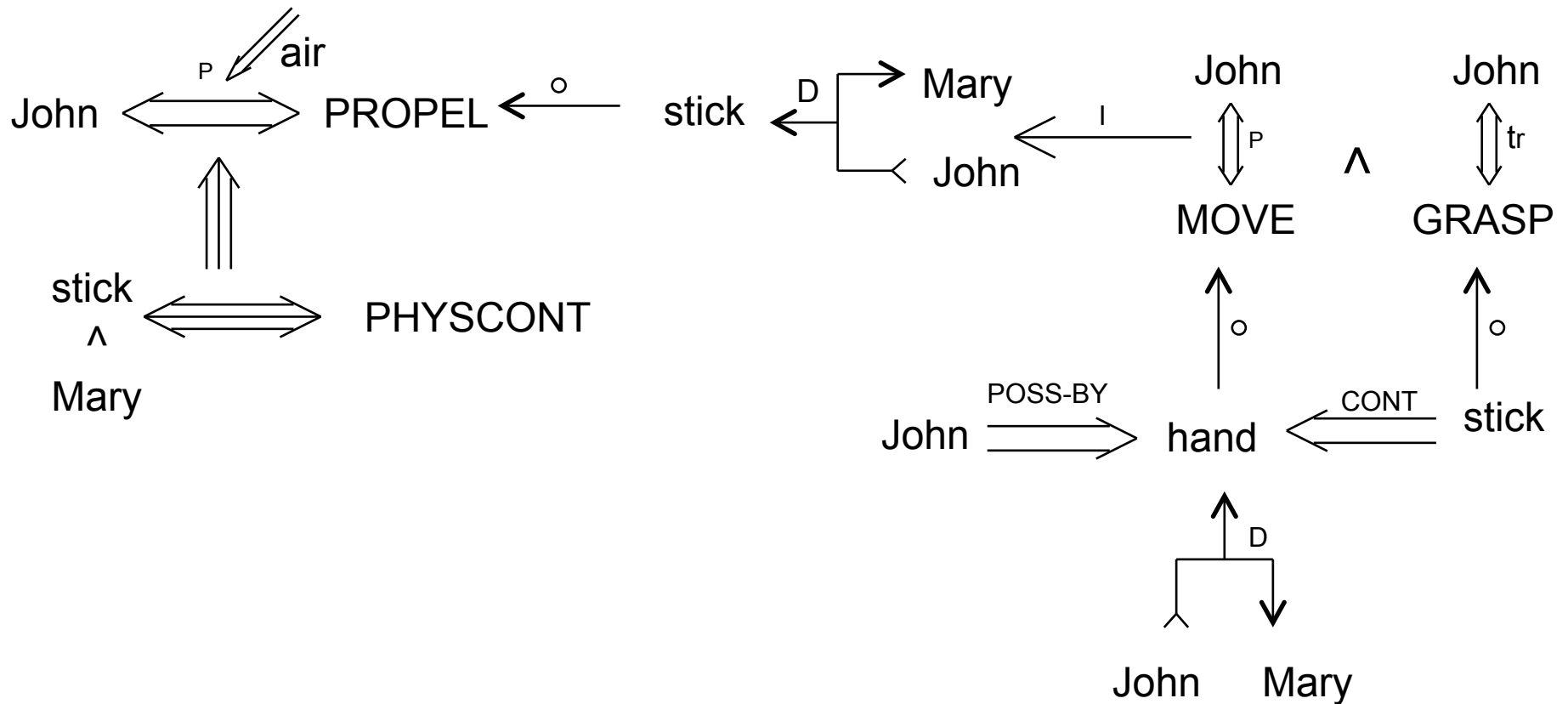


# John punched Mary

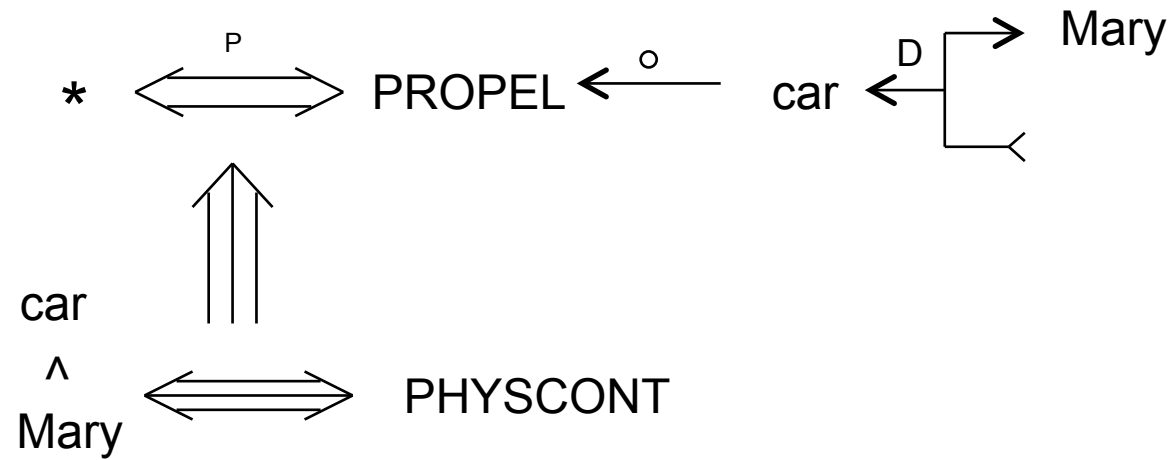


# More violence...

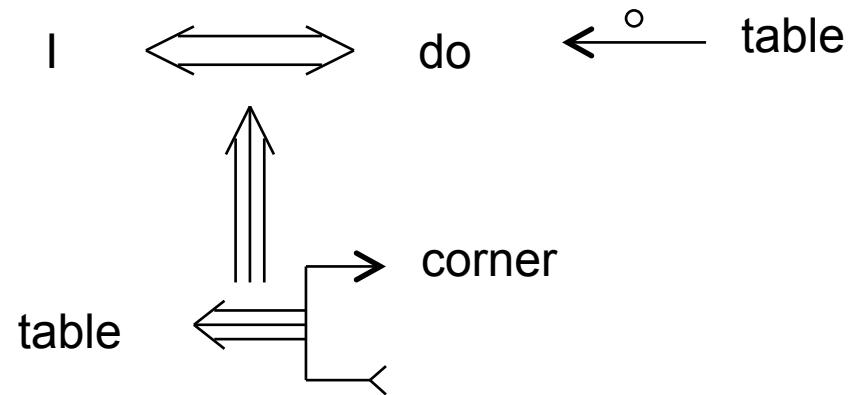
John hit Mary by throwing a stick at her.



# A car hit Mary.

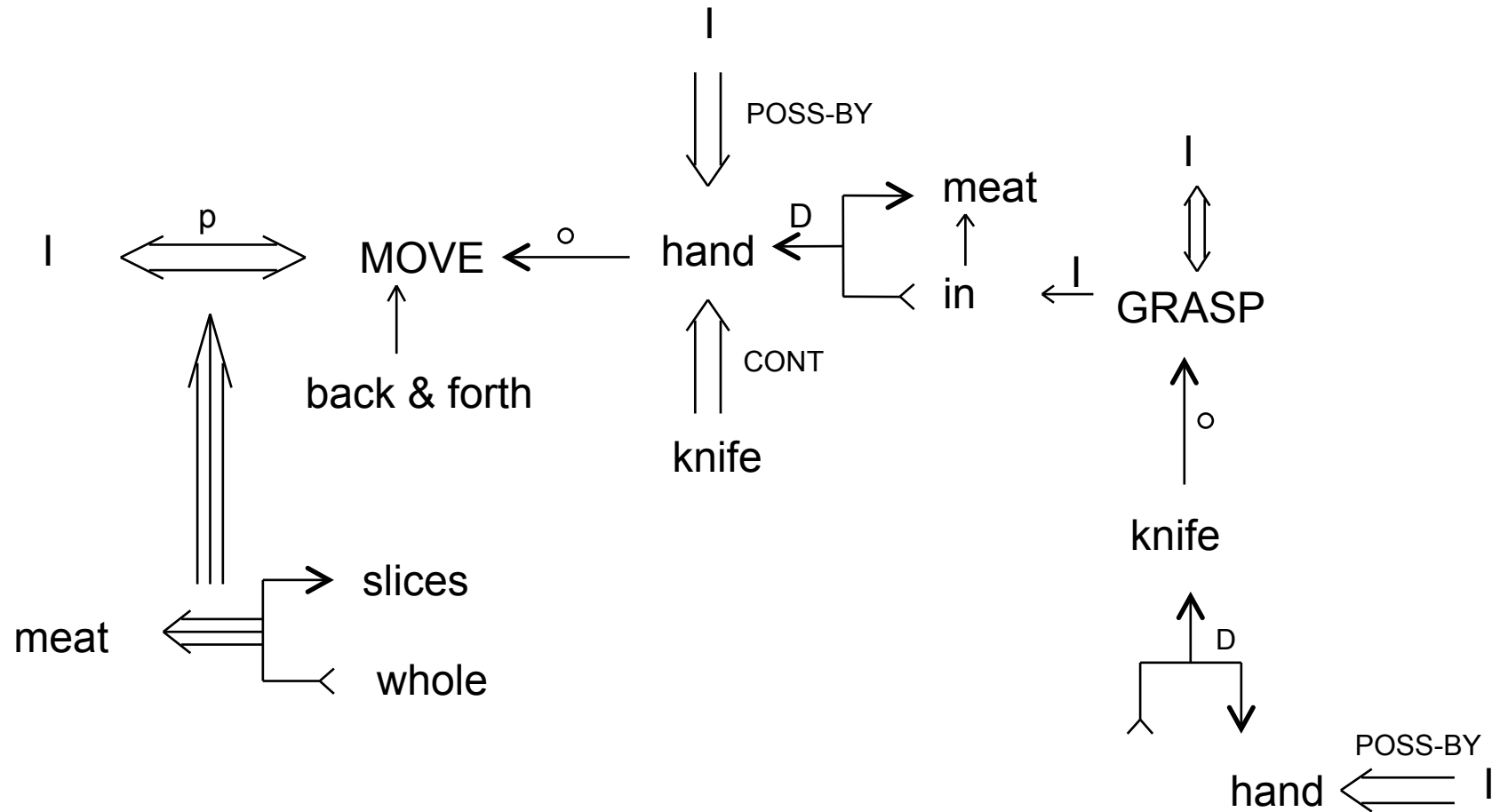


# I moved the table to the corner.



It could be possible that I PTRANSed the table by using PROPEL, but it could also be possible that I told someone to move it...

# I sliced the meat with a knife.

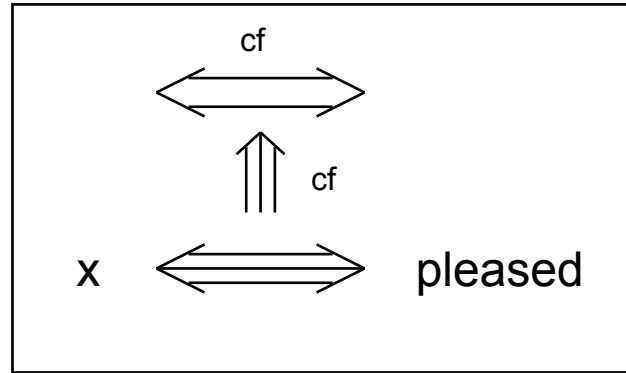


# Conceptual Analysis

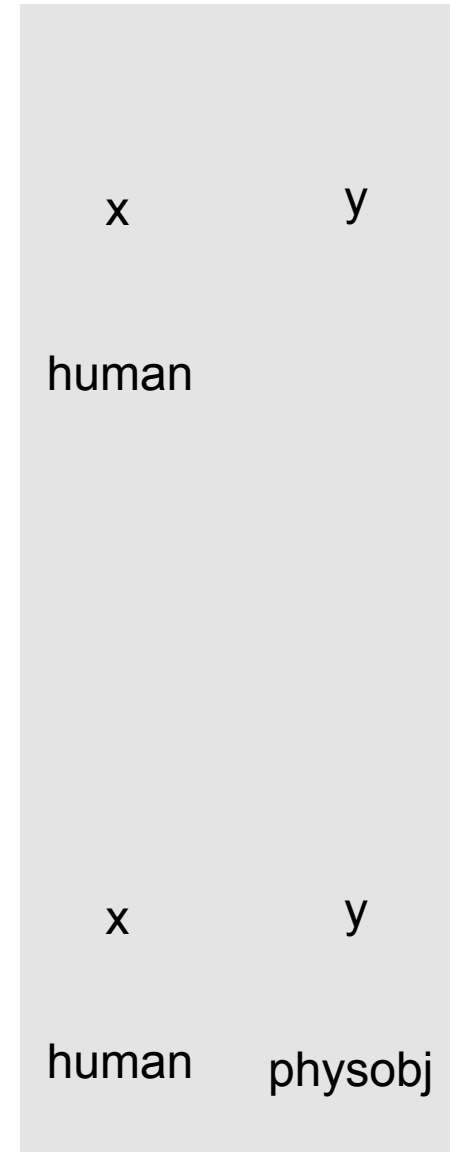
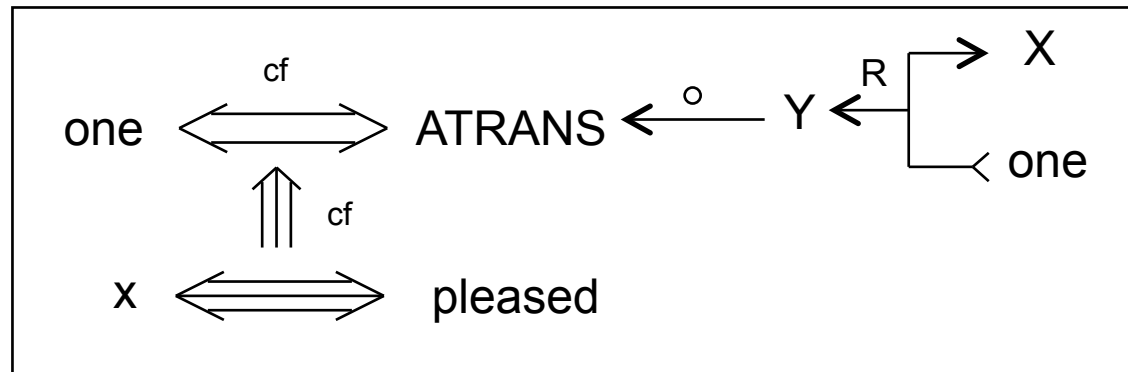
I want to go to the park with the girl.

want

vs



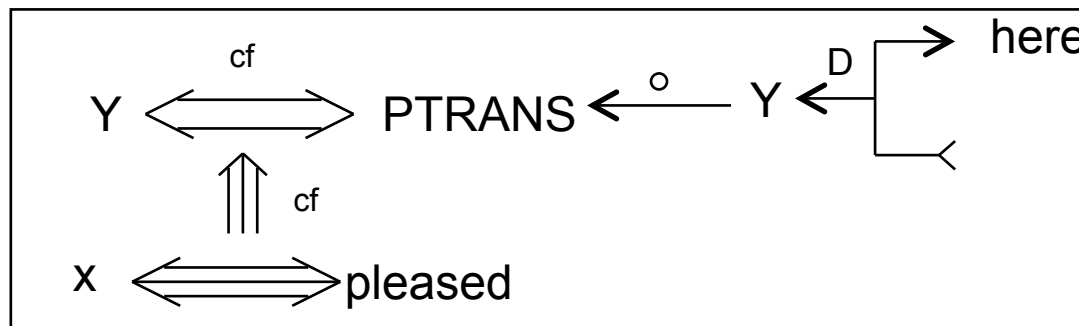
vt



# "want" – a third sense

want

vt



The first sense of want – state verb – is chosen. The parser is now on the lookout for a complete conceptualization to fill in.

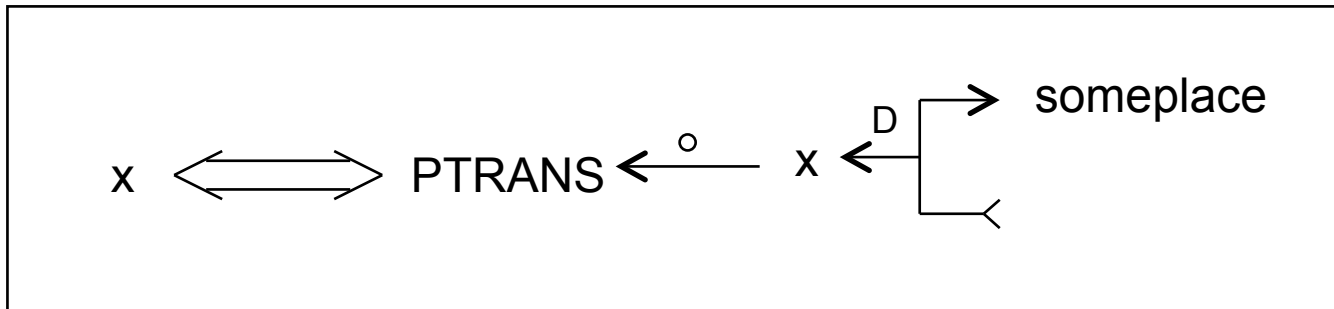
x	y
human	human



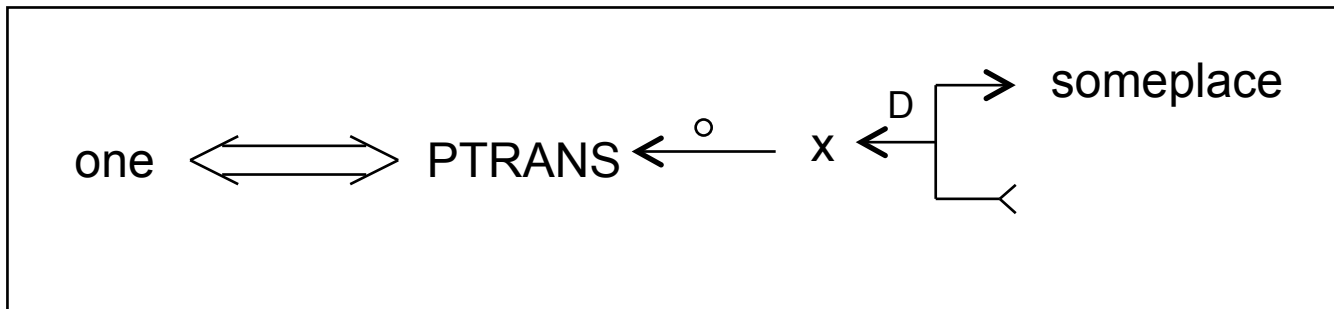
# I want TO GO...

go

vio



vio

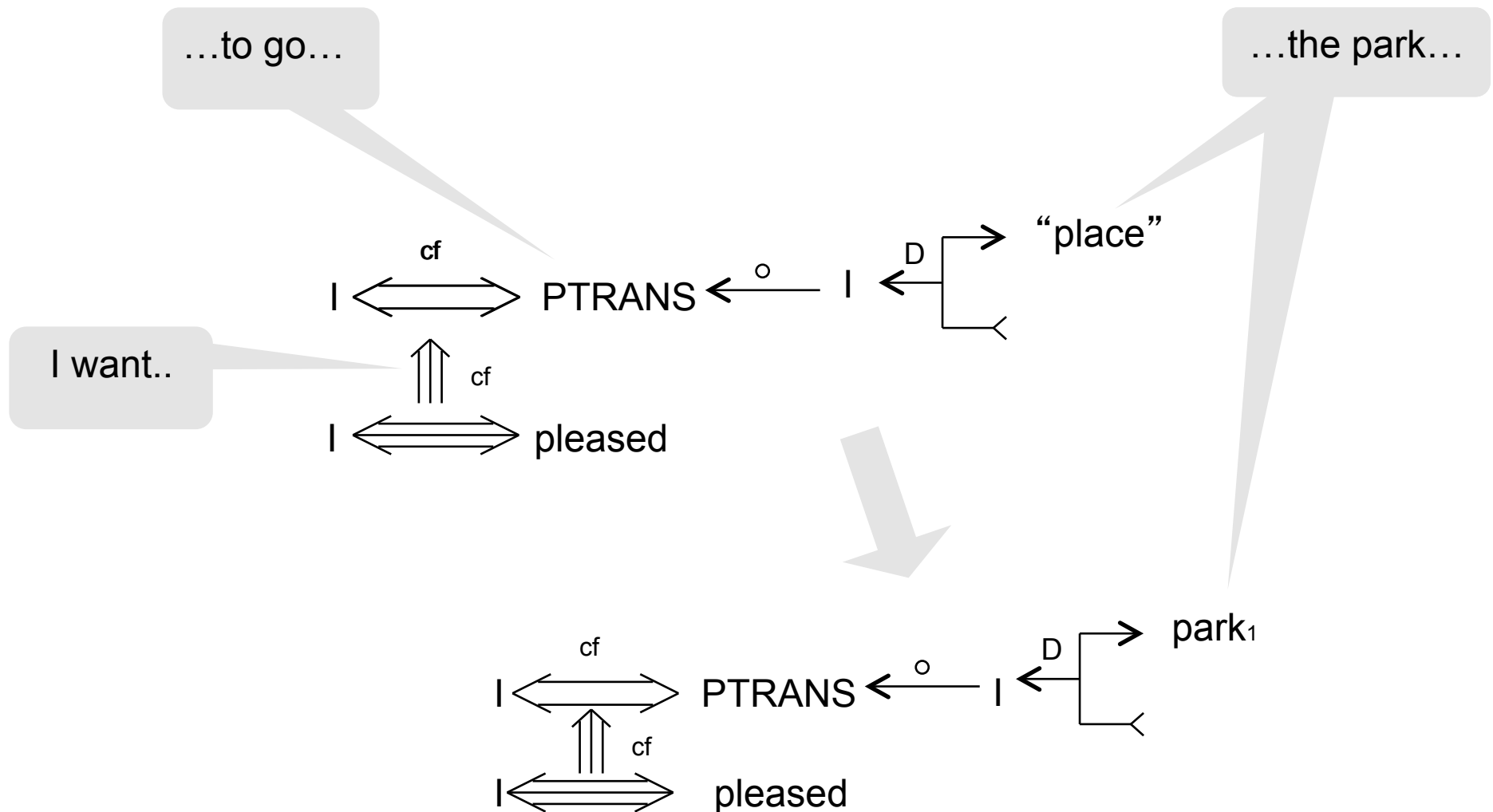


x

animal


physobj

# "to go" fulfills expectation of conceptualization



## ...with the girl

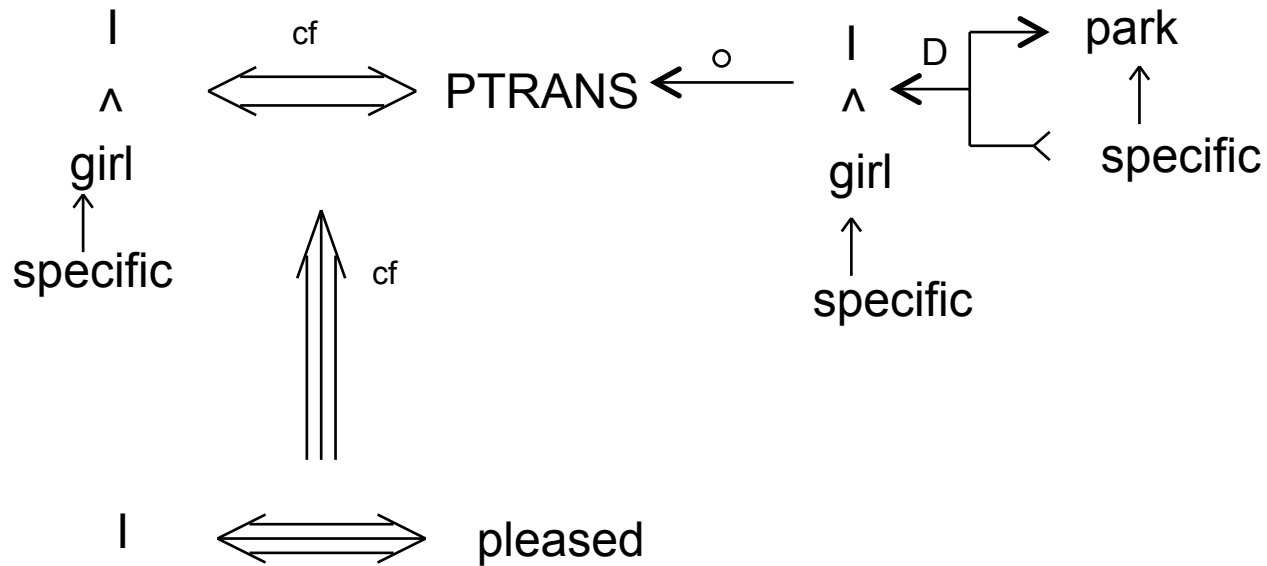
"with PP" has many conceptual possibilities.

1. PP is object of instrumental case (4)
2. PP is additional actor of the conceptualization (3) 
3. PP is an attribute of PP immediately preceding it (1,2,5)
4. PP is an attribute of the actor of the conceptualization (1,6)

Examples,

1. I went with a book to the park
2. I went to the park with the playground
3. I went with the girl to the park
4. I hit the boy with the bat
5. I hit the boy with the girl
6. I hit the boy with vengeance

# I want to go to the park with the girl.

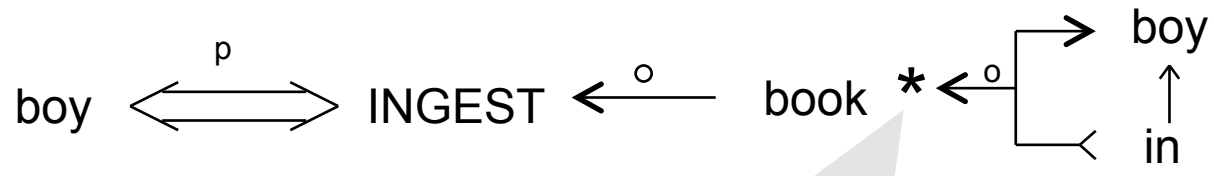


# Conceptual semantics

The boy ate a book



X	Y
animal	food

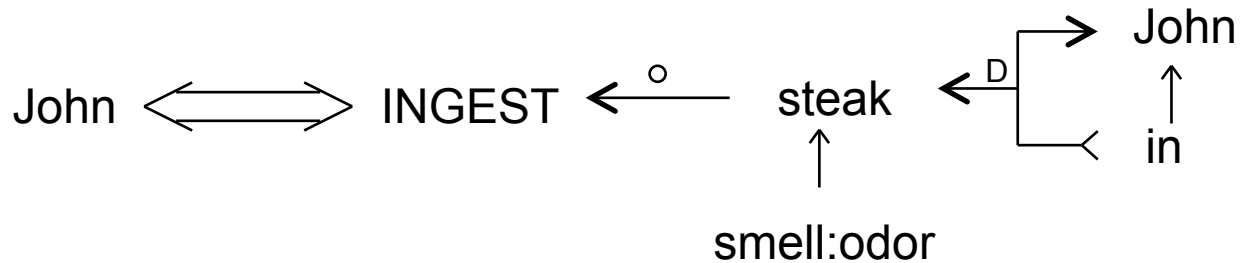


Given that there is no other word sense for eat, one has no choice... but one can mark the conceptualization is semantically inconsistent

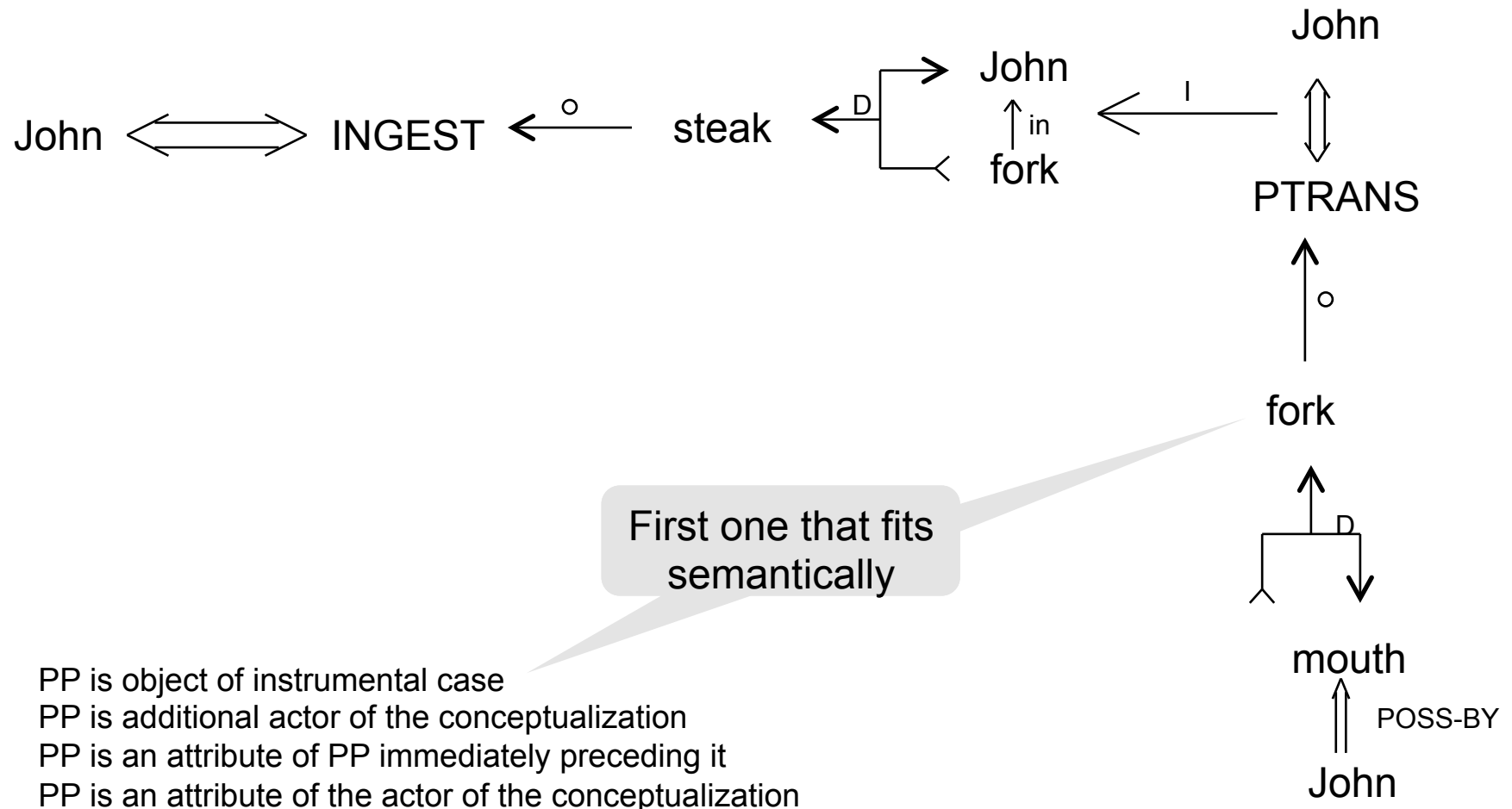
# John ate the steak with the odor

1. PP is object of instrumental case
2. PP is additional actor of the conceptualization
3. PP is an attribute of PP immediately preceding it
4. PP is an attribute of the actor of the conceptualization

First one that fits semantically



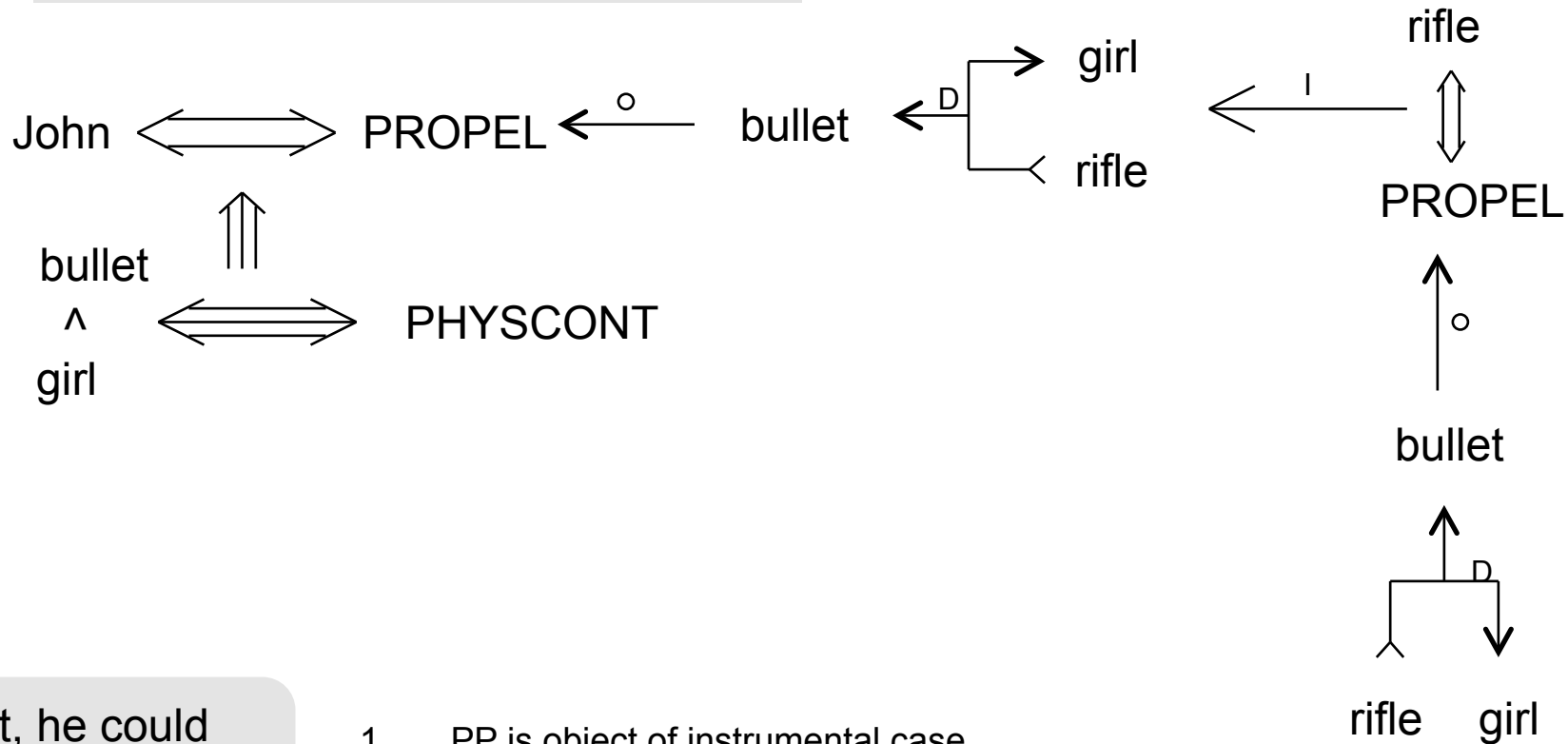
# John ate the steak with the fork



1. PP is object of instrumental case
2. PP is additional actor of the conceptualization
3. PP is an attribute of PP immediately preceding it
4. PP is an attribute of the actor of the conceptualization

# He shot the girl with a rifle

In the verb-ACT dictionary  
 "shoot" = PROPEL bullets from gun!



But, he could have been a photographer!

1. PP is object of instrumental case
2. PP is additional actor of the conceptualization
3. PP is an attribute of PP immediately preceding it
4. PP is an attribute of the actor of the conceptualization



## Syntactic ambiguity

Syntactic ambiguity has always been a problem in NLP.

Remember Kuno and Oettinger's "Time flies like an arrow".

Consider a sentence,

I saw the Grand Canyon flying to New York.

Most people are unwilling to accept a flying Grand Canyon and construct an appropriate structure in which one event marks the time of another.

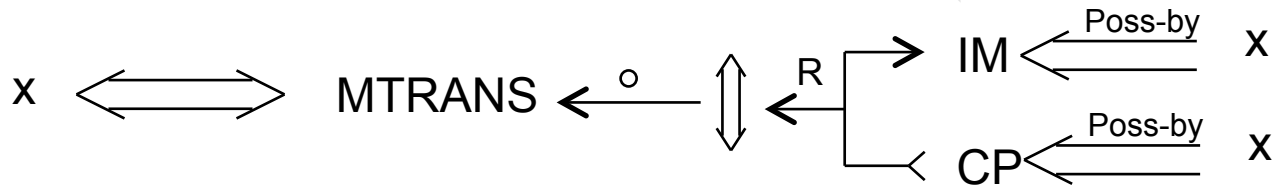
ELI also does this because it uses semantic information.

# Seeing

see

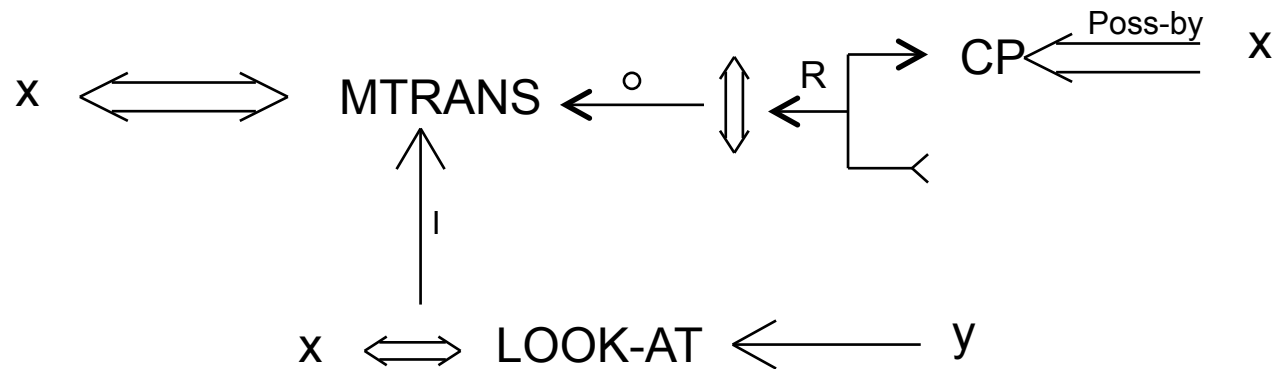
Understand,  
perceive

vi



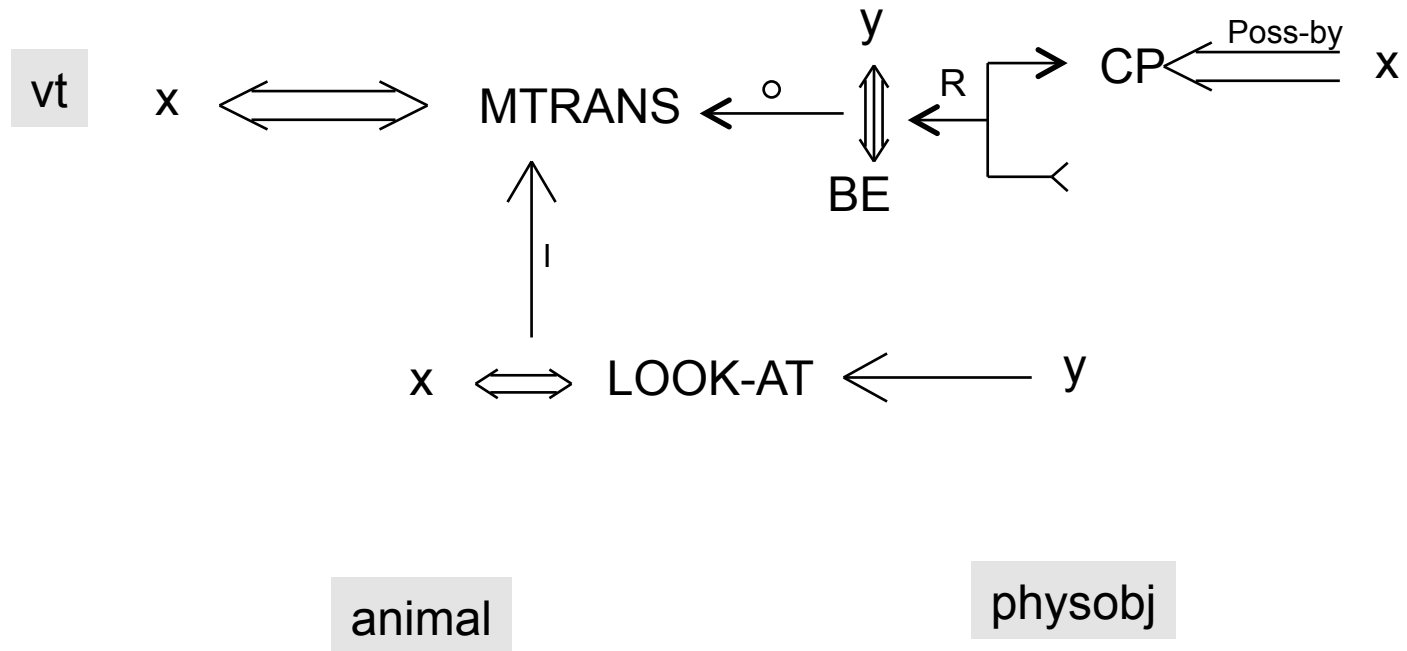
human

vs



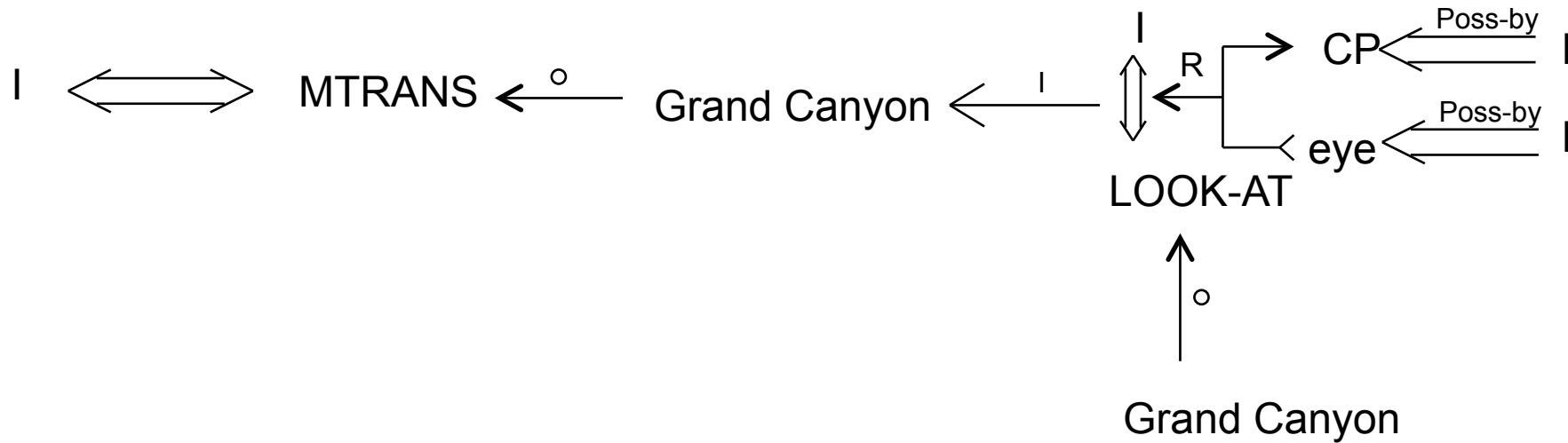
animal

# See



# I saw the Grand Canyon...

I saw the Grand Canyon flying to New York.

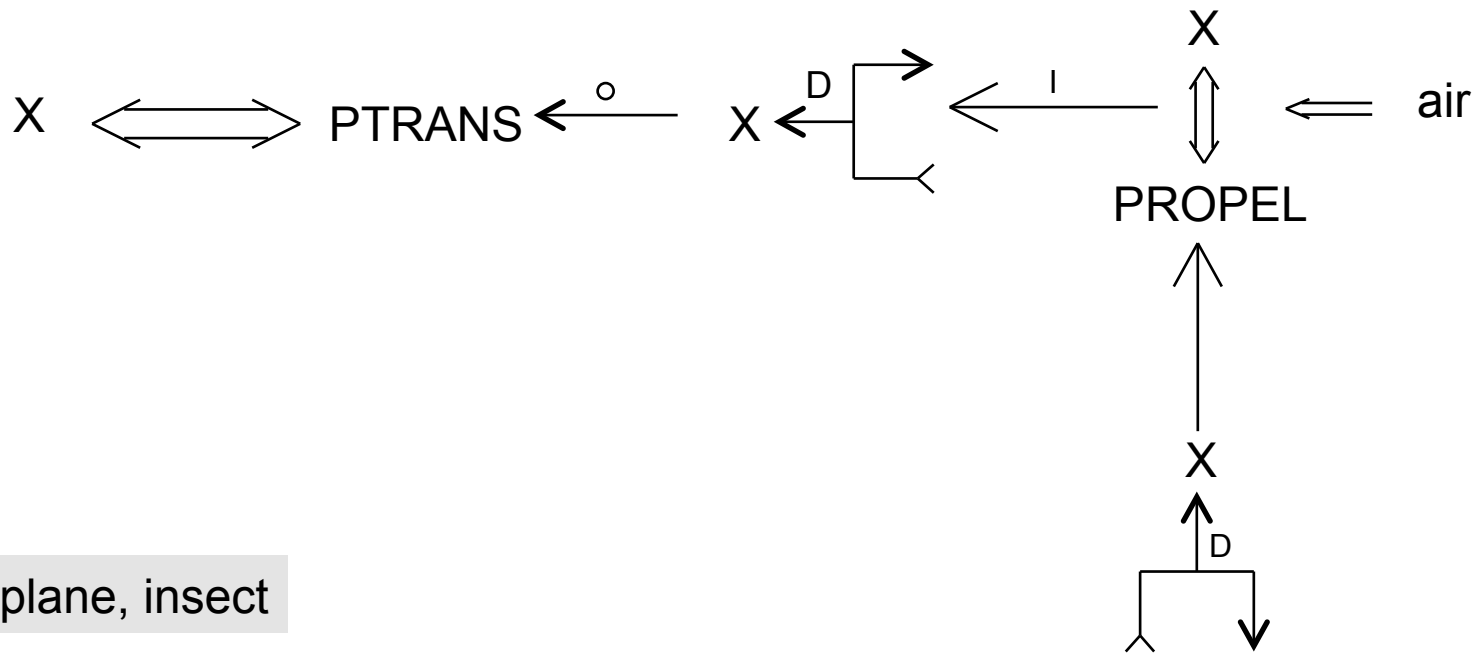


... flying (fly has three senses)

Birds, planes and insects can fly....

fly

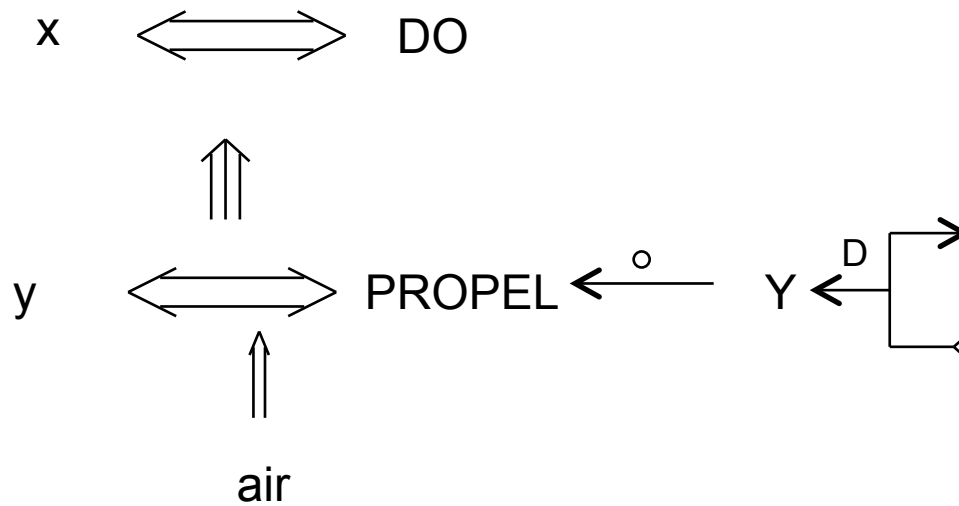
vio



bird, plane, insect

# Or humans can fly planes

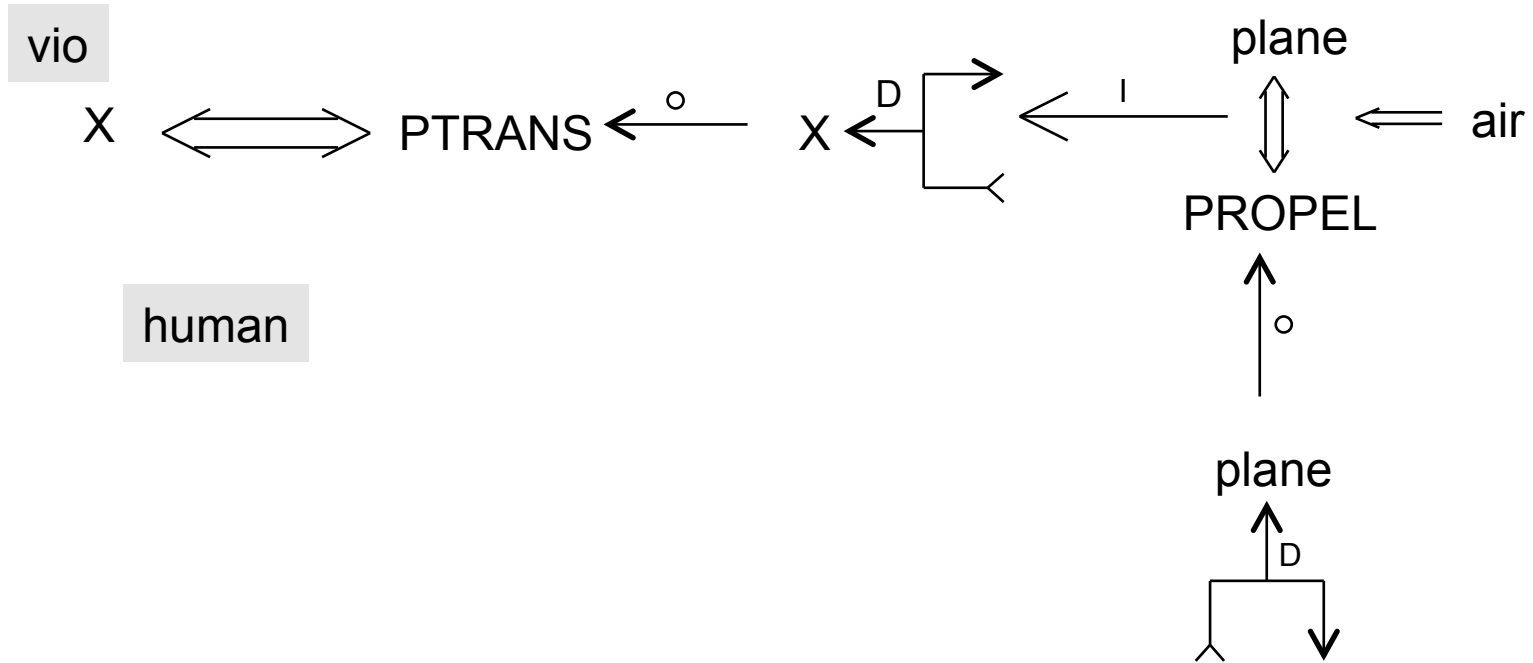
vt



human

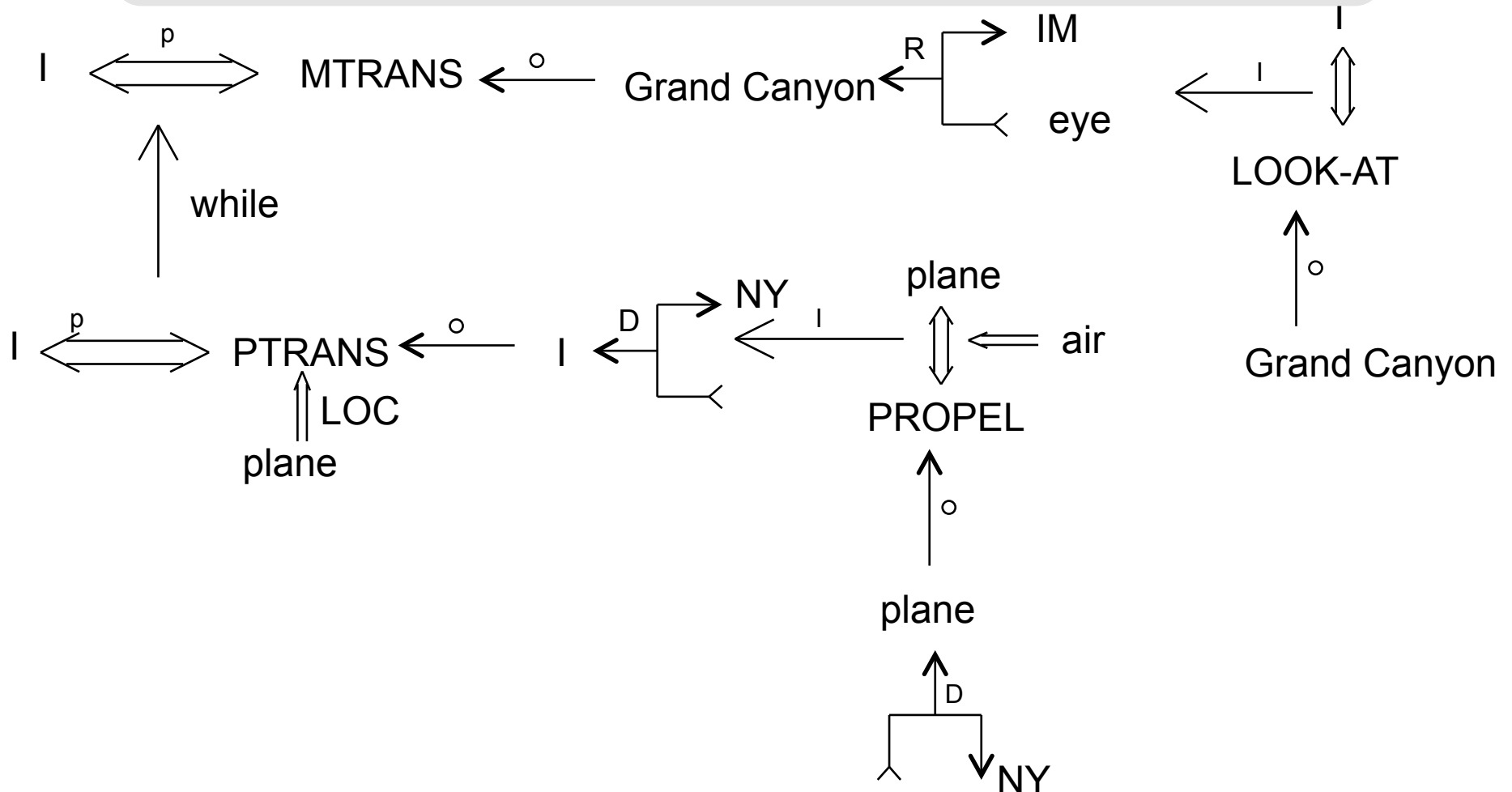
plane

# Or humans can fly in planes



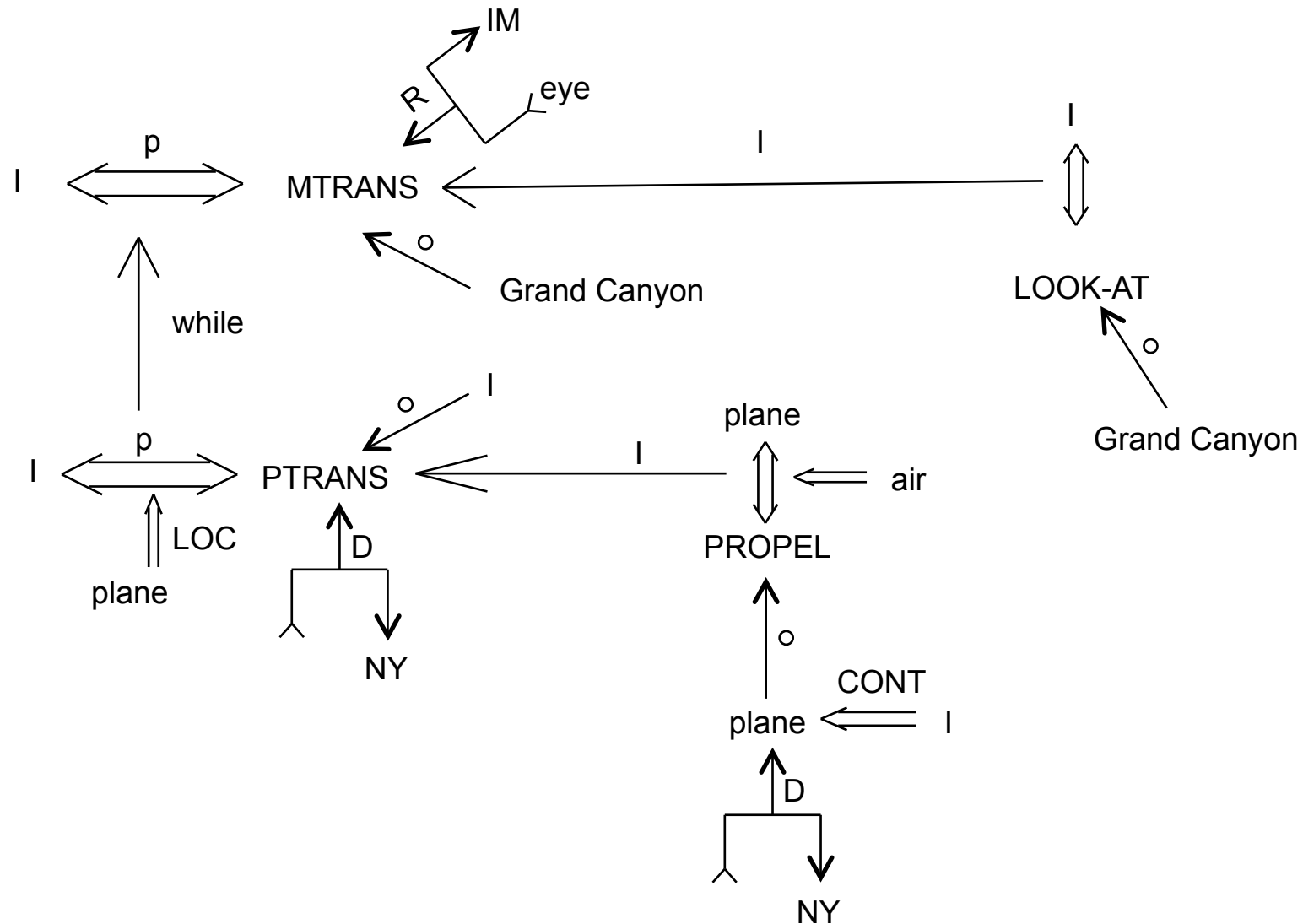
# I saw the Grand Canyon flying to New York

"I" am the only subject in the sentence, so the second or third form of fly must be used .... An English specific rule says that the second conceptualization marks the time of the first one.





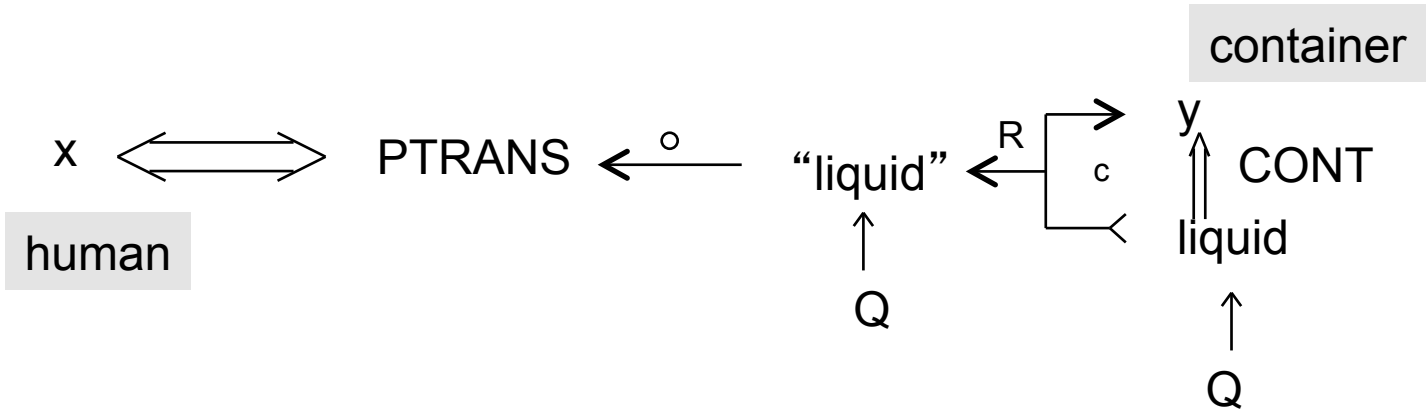
# I saw the Grand Canyon flying to New York



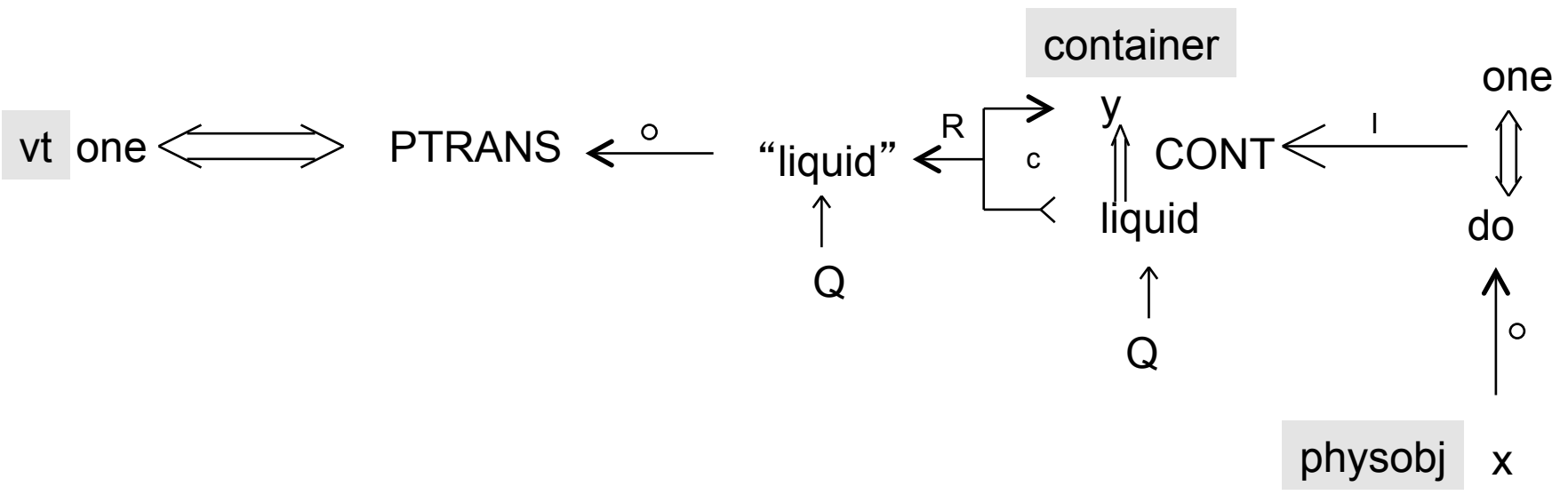
# Semantic Ambiguity

fill

vt



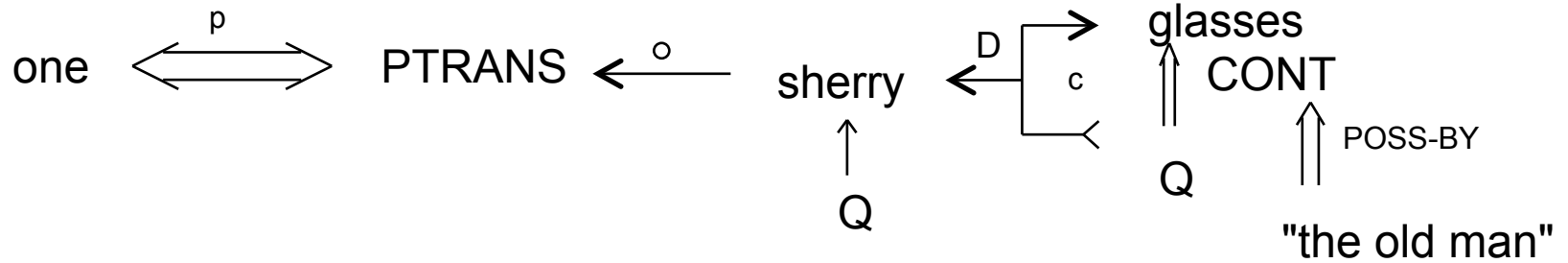
vt



# Semantic Ambiguity

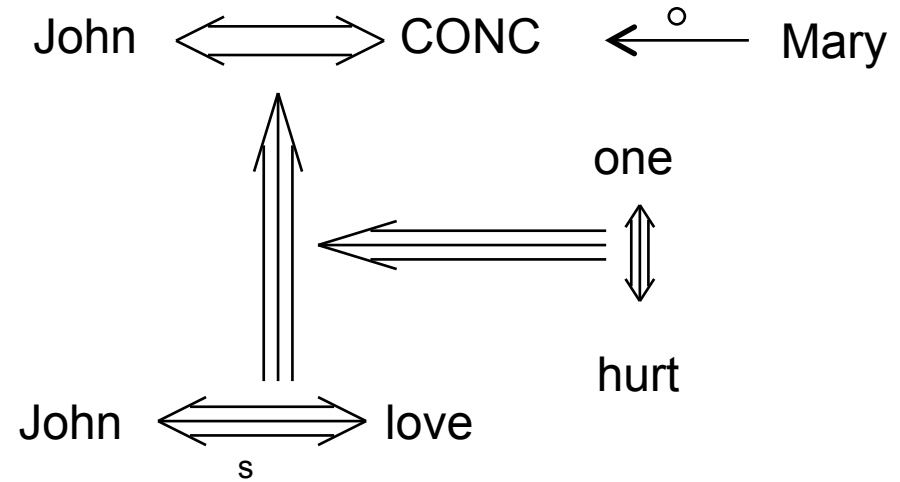
The old man's glasses were filled with sherry.

Glasses in the sense of containers!

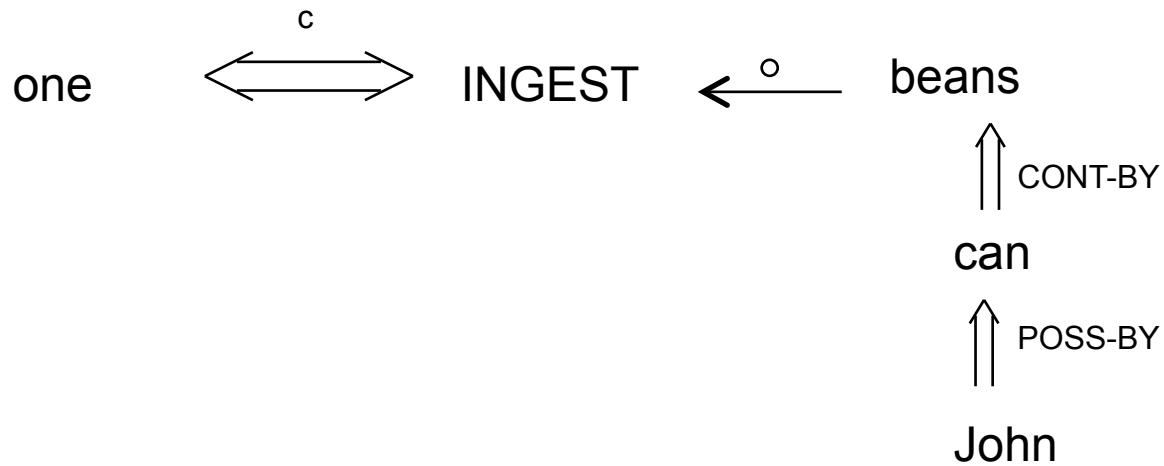


# Syntactic similarity

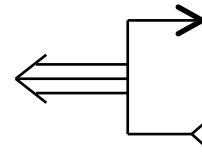
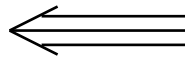
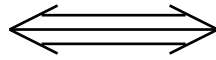
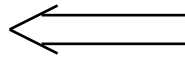
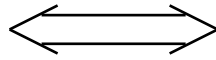
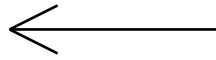
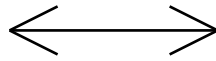
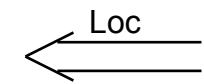
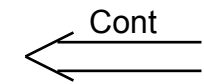
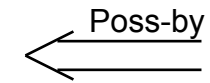
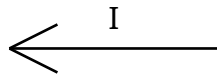
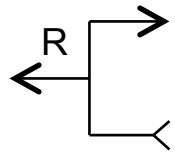
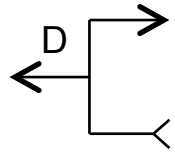
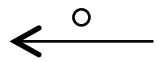
John's love of Mary was harmful.



John's can of beans was edible.



End



# Symbols

