# Formal Syntax and Semantics Meets Experimental Results

Some Remarks on the Comprehension of Definite NPs

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## The agenda

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| | |
|---|---|
| Intro: | Linguistic knowlege & language processing |
| 1 | Some experimental findings about processing |
| | - Referential expressions |
| | - Def. determiners (eye-tracking) |
| | - Def. determiners (synt. priming) |
| 2 | Apparent theoretical problems may sometimes have processing solutions |
| | - an experiment still to be done |
| 3 | Conclusions |

## Relations of cause and effect

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*Neurolinguistic and psycholinguistic accounts of human language are accounts of language processing and are built on cause-effect relations between physical events:*

- *temporally preceding events cause subsequent events*
- *there is no principled distinction between "linguistic" and other events involved in language processing - it's all activation of synaptic connections*
- *events can be monitored electrophysiologically at a granularity of milliseconds*

***There is no account of "gobal constraints" on these processes that say anything about central theoretical questions of wellformedness, interpretability, or productivity (i.e., linguistic knowledge)***

## Constituents and structural relations

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*Modern linguistics attempts to account for linguistic knowledge (wellformedness, interpretability, productivity) in terms of structural relations in constituent structure.*

- *It distinguishes strictly between linguistic knowledge and any other knowledge*
- *It does not describe language processing nor any other cognitive processes*
- *Structural derivations are not temporal processes and reflect nothing of the temporal order or complexity of cognitive processes*

## Some general findings from experimental work

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***Incrementality & Immediacy & Crossmodality***

- successive use of all information in the sequence in which it becomes available, to determine current processor action
- immediate use of all information that can be used,
- inclusion of information from all sources available

## Some examples

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Eye-Tracking experiments

Syntactic priming & lexical properties

## Eye-Tracking

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- Participants wear a device on their heads that makes a videotape showing exactly what they're looking at.
- They listen to spoken instructions and carry out various tasks.
- The eye-tracking provides evidence of the cognitive activity of participants that can be correlated with the linguistic input.
- No chance for reflection or intuition to interfere

## The gear

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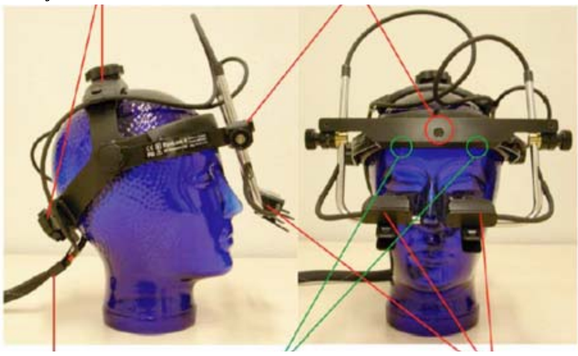
adjustable head set head camera



data cable corneal illuminators high-speed eye cameras

## The Paradigm: Visual World and lexical access

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Participants view a panel with typically four drawings of simple objects and they listen to instructions like

*Pick up the {pencil, glass, cup, coin,...}*

Participants' gaze regularly settles on a referent before the target word is completed,

unless the initial syllable of the word was consistent with more than one object in the display. E.g., when both a *pencil* and a *penny* were present, participants' gaze rested on the pencil more slowly

"Action" is taken

as soon as there is enough information

## Referential processing

Heute ist Markt im Dorf. Die Marktfrau streitet sich mit dem Arbeiter. Sie sagt jetzt gerade, dass er ihr nun das neue Fahrrad zurückgeben soll, das er sich geliehen hat.

It's market day in the village. The market woman is quibbling with the worker. She's just saying that he should give the new bike back that he has borrowed.

Karabanov, Bosch, König 2007

## Referential processing

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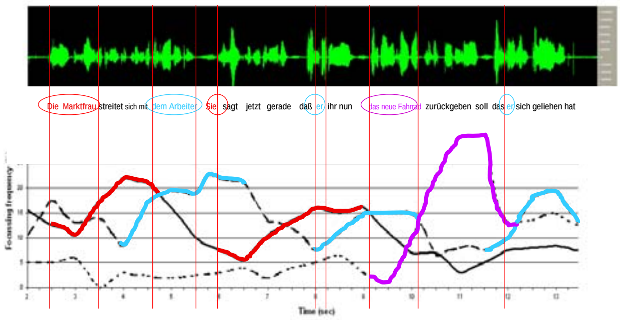
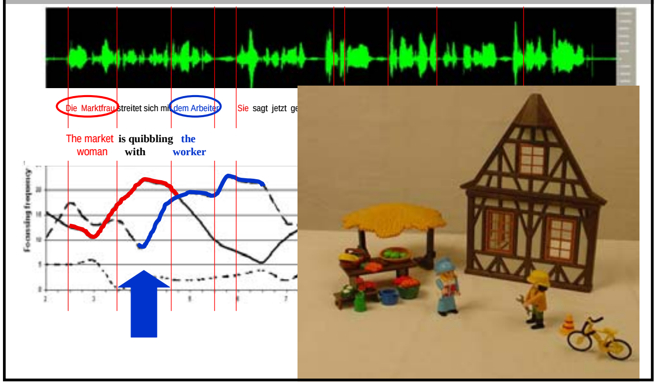


## Referential processing

**Referents are often anticipated on the basis of linguistic knowledge and whatever other information is available**




## Referential processing

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***What we expect if we take linguistic theory literally:***

- lexical access, expression by expression,
- parsing of string of expressions,
- once parsing is complete, for referential constituents:
  - lexical meaning determines a referent or
  - reference is resolved anaphorically, etc

***What we find:***

- syntactic position, phonology, and frequency information is used to predict/constrain next lexical item
- syntactic & semantic properties of lexical item, plus frequency information, predict next argument
- search for argument in visual domain starts before argument expression has even been uttered.

## Processing effects of the definite determiner?

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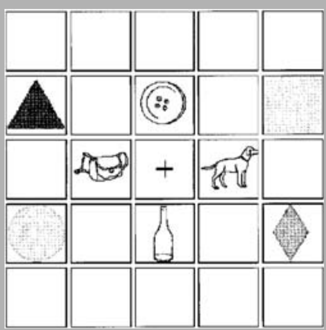
***cliquez sur le$_{[masc]}$ bouton$_{[masc]}$***
***[click on the button]***

***cliquez sur la$_{[fem]}$ bouteille$_{[fem]}$***
***[click on the bottle]***



D. Dahan, D. Swingley, M. K. Tanenhaus, & J. S. Magnuson: Linguistic Gender and Spoken-Word Recognition in French. Journal of Memory and Language **42,** 465–480 (2000)

## No processing effects!

***cliquez sur le$_{[masc]}$ bouton$_{[masc]}$ / cliquez sur la$_{[fem]}$ bouteille$_{[fem]}$***

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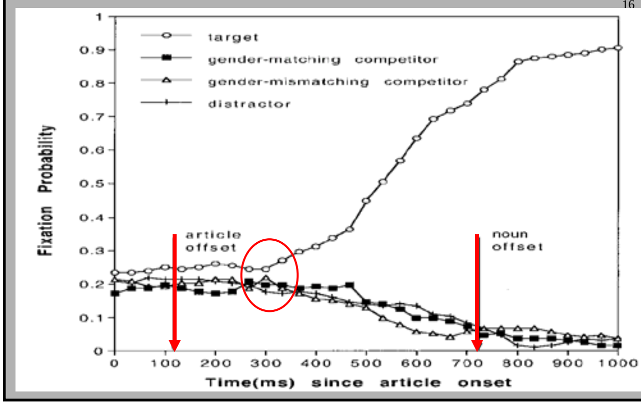


## ... and the same for German ?

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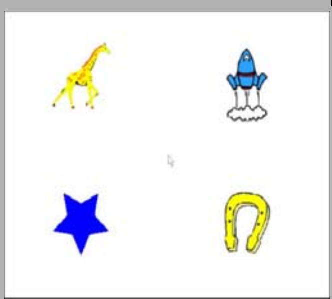
default nouns:

*die$_{[fem]}$ gelbe Giraffe$_{[fem]}$*
*the yellow giraffe*

*die$_{[fem]}$ blaue Rakete$_{[fem]}$*
*the blue rocket*

*der$_{[masc]}$ blaue Stern$_{[masc]}$*
*the blue star*

*das $_{[neut]}$ gelbe Hufeisen$_{[neut]}$*
*the yellow horse shoe*



*Klicken Sie auf die blaue Rakete.*

*click on* ... [followed by a def. determiner, adjective, and noun]

Hartmann 2005

## *Klicken Sie auf die gelbe Giraffe*

(die gelbe Giraffe/ die gelbe Banane/ das rote Hufeisen/der blaue Stern)

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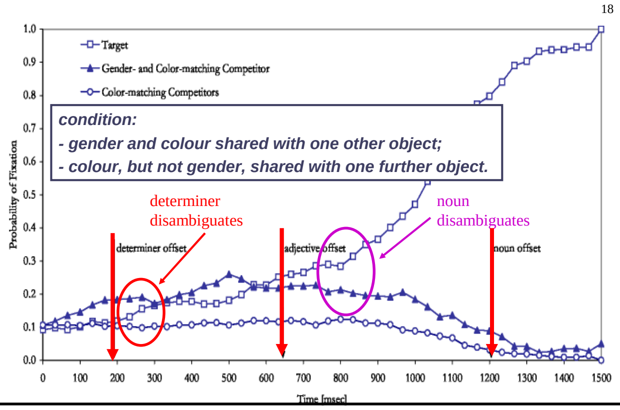
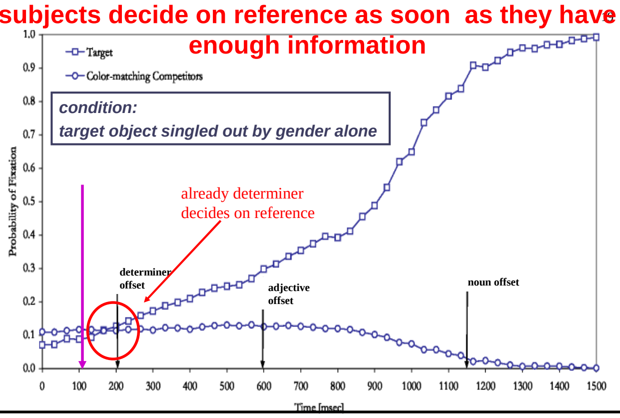


## *Klicken Sie auf die gelbe Giraffe*
(die gelbe Giraffe/ das rote Auto/ der blaue Stern/ der grüne Baum)

**subjects decide on reference as soon as they have enough information** 19




## What do we learn from this?

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*Russell says that the definite determiner has no meaning in isolation, but only in the context of a proposition - which literally gives us no meaning for the determiner.*

*Frege models the denotation of the determiner as a partial function, relative to a domain:*

$\lambda f \in D_{<e,t>} \& \exists! x f(x)=1 . \iota y[f(y)=1]$

*Suppose this is actully part of an entry in the mental lexicon:*

*Then, as long as f is not known, the determiner still could not have any processing effect.*

*But does our experiment not demonstrate the contrary?*

## Ingredients for an explanation

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The display limits the choice to four objects, for which linguistic experience provides default nouns, only one of which happens to be "gender-congruent" with the determiner. – So the processing effect of the determiner could be explained by assuming

- an entry in the mental lexicon that makes the noun *Stern* [...gen:masc] the default description for ⟦star⟧ instances,
- an identification of exactly one display object as an instance of ⟦star⟧,
- the subsumption of all other display objects under concepts with non-gender-congruent default nouns
- and a lexical entry for *der* including gender information $\lambda f \in D_{<e,t>} \& \exists! x f(x) \& g(x,masc)=1 . \iota y[f(y)=1]$

## Ingredients for an explanation

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*But how much of this is linguistic knowledge?*

- *Linguistic knowledge alone would not explain the observed processing effect.*

- an entry in the mental lexicon that makes the noun *Stern* [...gen:masc] the default description for ⟦star⟧ instances,
- an identification of exactly one display object as an instance of ⟦star⟧,
- the subsumption of all other display objects under concepts with non-gender-congruent default nouns
- and a lexical entry for *der* including gender information $\lambda f \in D_{<e,t>} \& \exists! x f(x) \& g(x,masc)=1 . \iota y[f(y)=1]$

## The mechanism

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*Given this linguistic and non-linguistic information – How is it processed?*

*the (Neo-) Gricean way?*

*if the speaker believes... then he would...*

*This is unlikely. Given the speed of the effect (100-200 ms), there is no time for reasoning.*

*More likely, the process is modular: fast, unconscious, mandatory*

## Syntactic priming experiment 1: Setup

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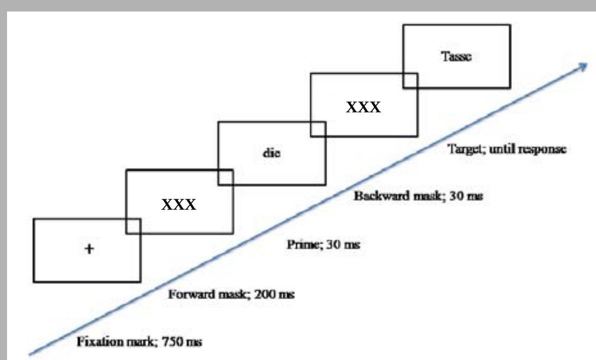
subliminal




Kempa 2007

## Syntactic priming experiment 2: Setup

supraliminal

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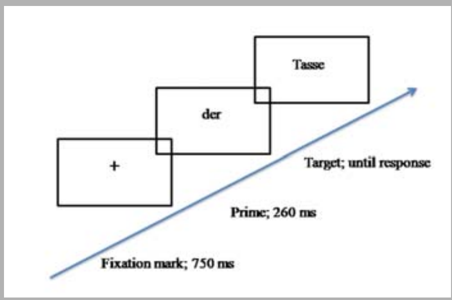


Kempa 2007

## Syntactic priming experiments: Materials

16 prime-target pairs

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| | feminine | masculine |
|---|---|---|
| congruent | die Gabel<br>die Tasse<br>die Hand<br>die Nase | der Löffel<br>der Teller<br>der Arm<br>der Mund |
| incongruent | der Gabel<br>der Tasse<br>der Hand<br>der Nase | die Löffel<br>die Teller<br>die Arm<br>die Mund |

Kempa 2007

## Syntactic priming experiments: Results

**Average reaction times (from noun onset to button press)** 27

| | congruent | incongruent | delta |
|---|---|---|---|
| subliminal | 727 ms | 747 ms | 20 ms |
| supraliminal | 738 ms | 787 ms | 49 ms |

**Error rates** no significant difference between conditions

There is a difference between feminine (faster) and masculine (slower) nouns that is probably explained by the syncretism of the definite determiner

(Kempa 2007, rough first reporting)

## The lesson for determiner processing

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***Gender information in the determiner is processed automatically, with no interference of conscious processes, in a modular fashion***

***(demonstrated by the subliminal condition)***

***and, due to (unconscious) linguistic knowledge about congruence, the determiner gender predicts the gender of the following noun***

***(demonstrated by the temporal advantage gained in the congruent condition)***

## When and how does uniqueness enter?

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***The German definite determiner carries information not only about the gender of the head noun, its number and case***

***but also a condition about <u>uniqueness and existence</u> of the referent of the nominal:***

$$\lambda f \in D_{<e,t>} \& \exists ! x f(x)=1 . \iota y [f(y)=1]$$

***Is this information also retrieved and used immediately, upon the recognition of the determiner?***

***How does it influence the parsing and referential processing of the nominal?***

## A scenario and an instruction:

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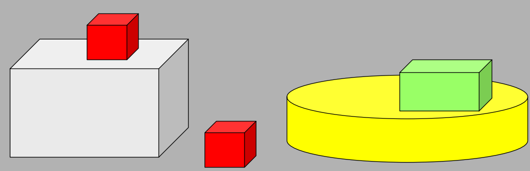
*put the red cube on the block on the disk.*



## A scenario and an instruction: Likely result

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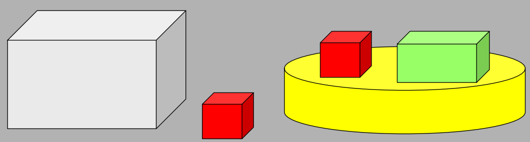
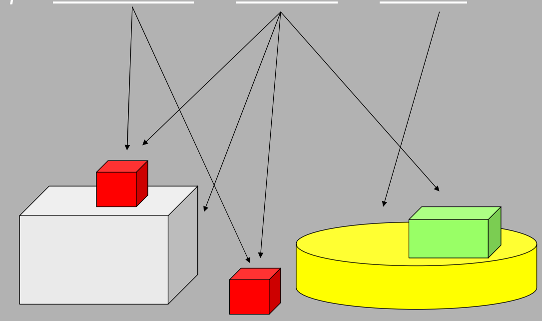
*put the red cube on the block on the disk.*



*put the red cube on the block on the disk.*

32



*A. put [the red cube] [on [the block [on [the disk]]]]*

*B. put [the [red [cube [on [the block]]]]] [on the disk].*

***A. put [the red cube] [on [the block [on [the disk]]]]***

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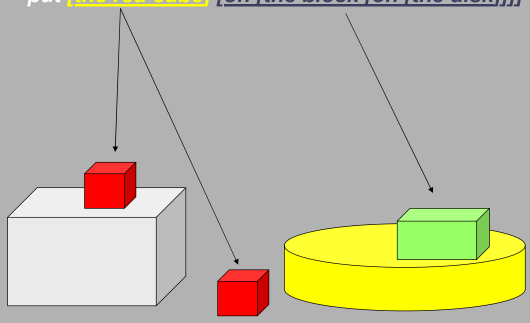

***B. put [the [red [cube [on [the block]]]]] [on the disk].***

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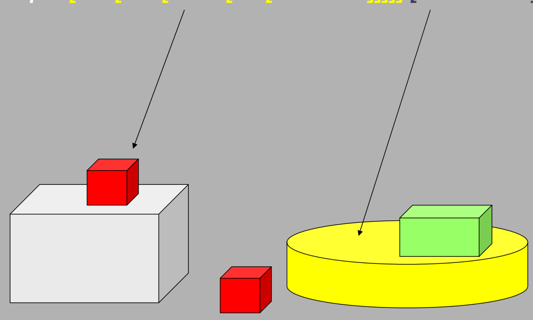

Only parse B fits the scenario.

How is it seleceted as the first and "natural" analysis?

## 2 syntactic structures, but domain selects only 1

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**Only one of the syntactic analyses leads to a structure that could (in principle) be interpreted for the given reference domain.**

**But current methods of compositional semantics don't allow us to carry out the corresponding derivation:**

> ***Each constituent denotation must be computed before it can become part of the denotation of a larger constituent.***

***[put [the [red [cube [on [the block]]]]]] [on [the disk]].***

## Attempted derivation

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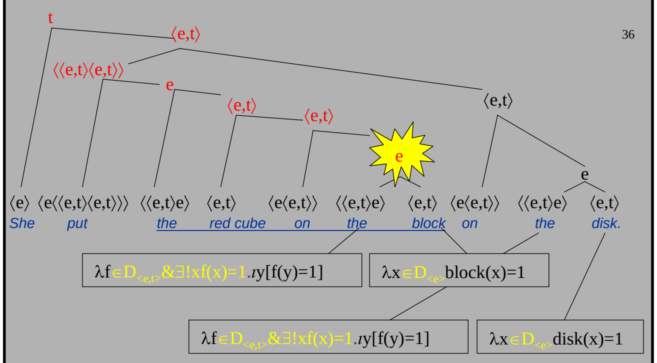

$\lambda f \in D_{<e,t>} \& \exists! x f(x)=1 . \iota y[f(y)=1]$

domain condition satisfied !

⟨e⟩ ⟨e⟨⟨e,t⟩⟨e,t⟩⟩⟩ ⟨⟨e,t⟩e⟩ ⟨e,t⟩ ⟨e,t⟩ ⟨e⟨e,t⟩⟩ ⟨⟨e,t⟩e⟩ ⟨e,t⟩ ⟨e⟨e,t⟩⟩ ⟨⟨ ⟨e,t⟩

*She put the red cube on the block on the disk.*

needed: a property ***g*** that makes an entity a unique instance of something on which there is a red cube

$[\lambda x_e \lambda y_{\langle e,t\rangle}.\mathrm{PUT}(a,x,y)]$ ⟨e ⟨⟨e,t⟩t⟩⟩

$\lambda f_{\langle e,t\rangle} \exists! x f(x)\ \lambda y_{\langle e,t\rangle}.\mathrm{PUT}(a,\iota z.f(z),y)$

$\lambda f_{\langle e,t\rangle} \exists! x(f(x)\&\mathrm{RED}(x))\ \lambda y_{\langle e,t\rangle}.\mathrm{PUT}(a,\iota z.f(z),y)$

$\lambda f_{\langle e,t\rangle} \exists! x(f(x)\&\mathrm{RED}(x)\&\mathrm{CUBE}(x))\ \lambda y_{\langle e,t\rangle}.\mathrm{PUT}(a,\iota z.f(z),y)$

$\lambda v_e\ \lambda f_{\langle e,t\rangle} \exists! x(f(x)\&\mathrm{RED}(x)\&\mathrm{CUBE}(x)\&\mathrm{ON}(x,v))\ \lambda y_{\langle e,t\rangle}.\mathrm{PUT}(a,\iota z.f(z),y)$

$\lambda g_{\langle e,t\rangle} \exists! w g(w)\ \lambda f_{\langle e,t\rangle} \& \exists! x(f(x)\&\mathrm{RED}(x)\&\mathrm{CUBE}(x)\&\mathrm{ON}(x,\iota u.g(u)))\ \lambda y_{\langle e,t\rangle}.\mathrm{PUT}(a,\iota z.f(z),y)$

$\lambda f_{\langle e,t\rangle} \exists! x(f(x)\&\mathrm{RED}(x)\&\mathrm{CUBE}(x)\&\mathrm{ON}(x,\iota u.\mathrm{BLOCK}(u)\&\mathrm{ON}(x,u)\&\mathrm{RED}(x)\&\mathrm{CUBE}(x)))\ \lambda y_{\langle e,t\rangle}.\ \mathrm{PUT}(a,\iota z.f(z),y)$

$\lambda y_{\langle e,t\rangle}.\mathrm{PUT}(a,\iota z.\mathrm{RED}(z)\&\mathrm{CUBE}(z)\&\mathrm{ON}(z,\iota v.\mathrm{BLOCK}(v)),y)$

$\mathrm{PUT}(a,\ \iota z.\mathrm{RED}(z)\&\mathrm{CUBE}(z)\&\mathrm{ON}(z,\iota v.\mathrm{BLOCK}(v)),\ \mathrm{ON}(\iota x.\mathrm{DISK}(x)))$

***She put the red cube on the block on the disk.***

## What have we done differently?

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- *no change in lexical entries*
- *no change in other constraints on wellformedness*
- *no change in constituent structure*

*The only deviation from common accounts is in adding to the domain condition of the determiner denotation a description of <u>states of the processor</u>, which records*

- *constraints on reference (to things and concepts)*
- *constraints on the type of information still required for the completion of constituents*

*and in comparing these constraints in each step with the domain.*

## Summing up

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*The idea is to change as little as possible in our <u>theories of linguistic knowledge</u>*

*and build a <u>theory of language processing</u> that uses what we already know about linguistic knowledge.*

*What's the advantage of that? - as usual: Modularity.*

*We don't want to deal with processing matters in the theory of linguistic knowledge & we don't want to mistake processor properties for properties of language.*

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***T h a n k  y o u !***