Semantics, action and perception - an overview of TTR

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https://sites.google.com/site/typetheorywithrecords/slides

Outline

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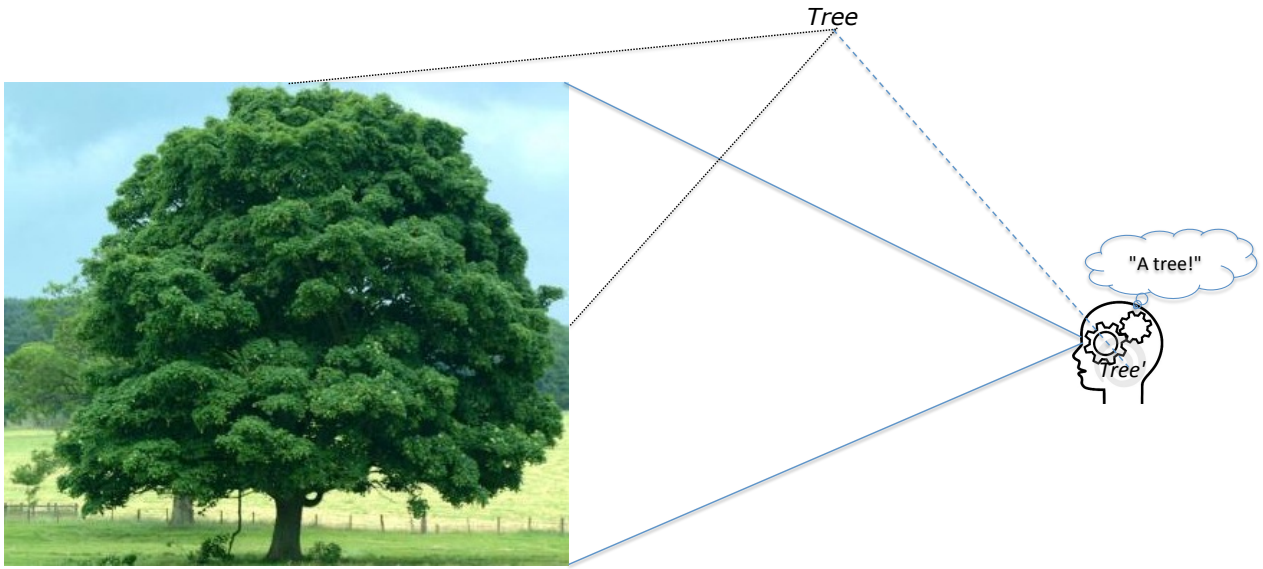
Seeing a tree (a simulation view)



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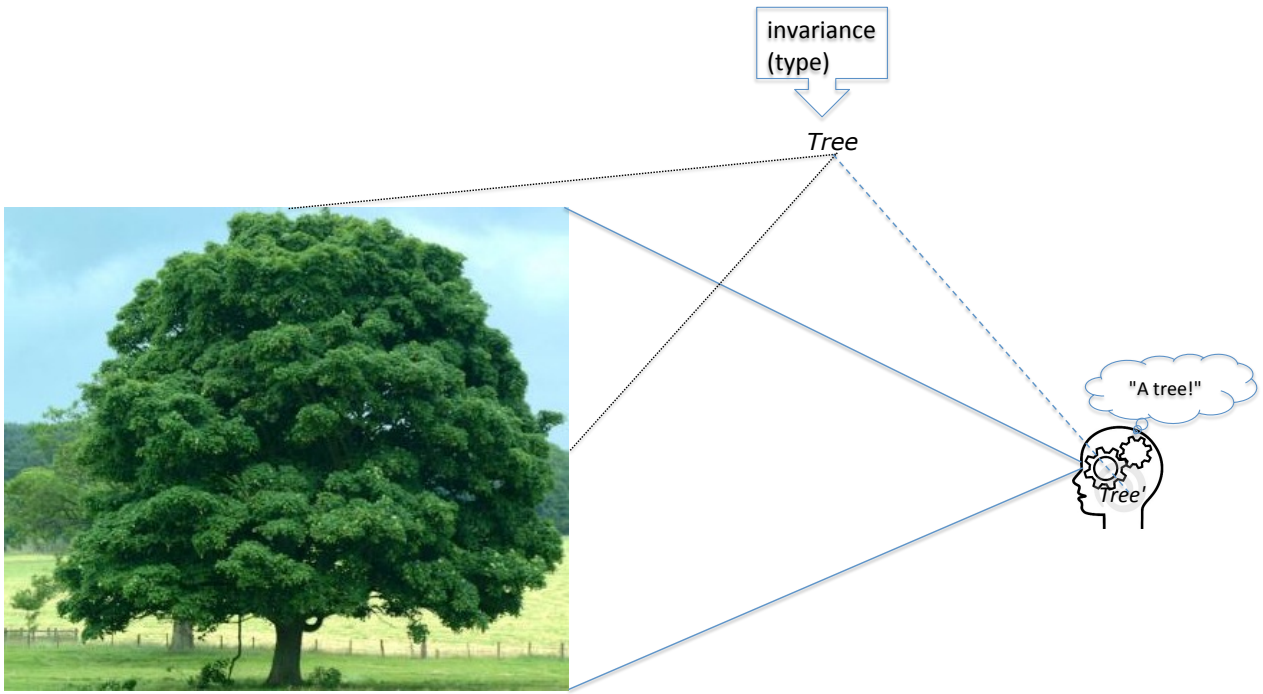

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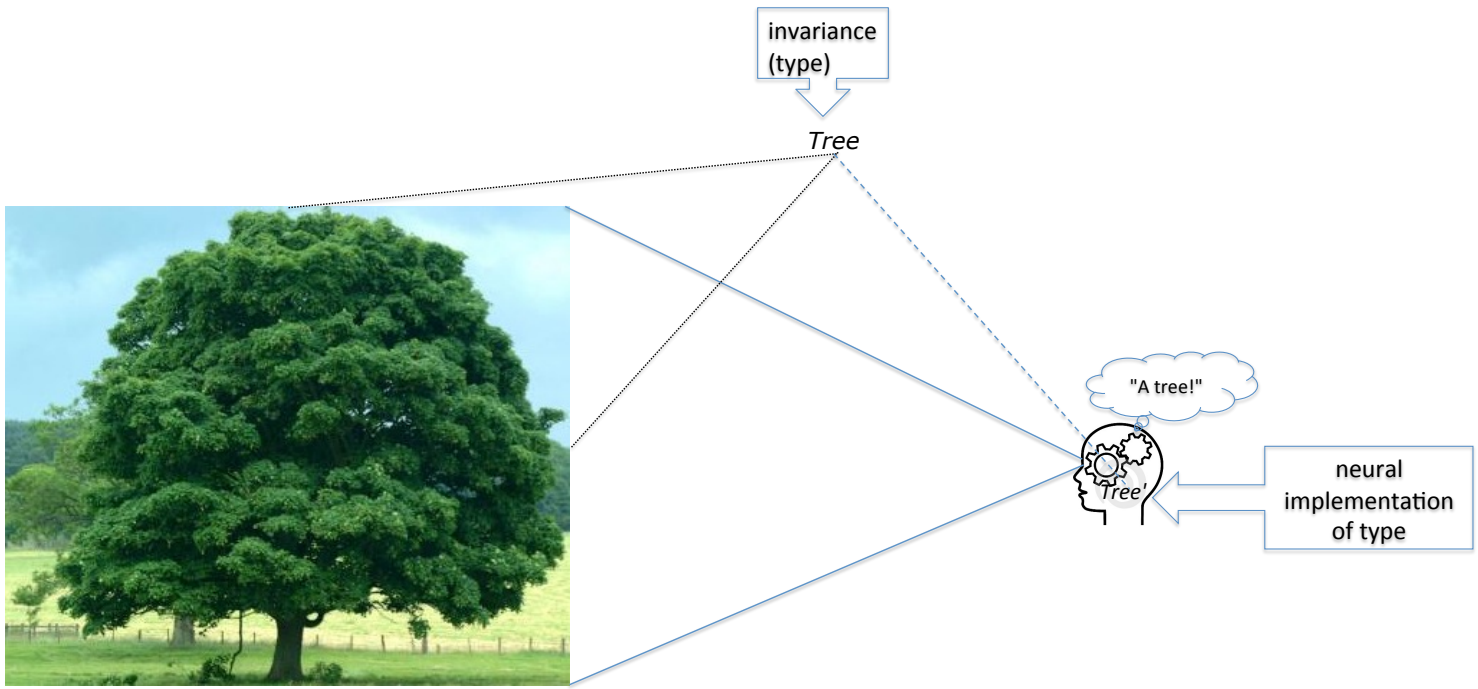

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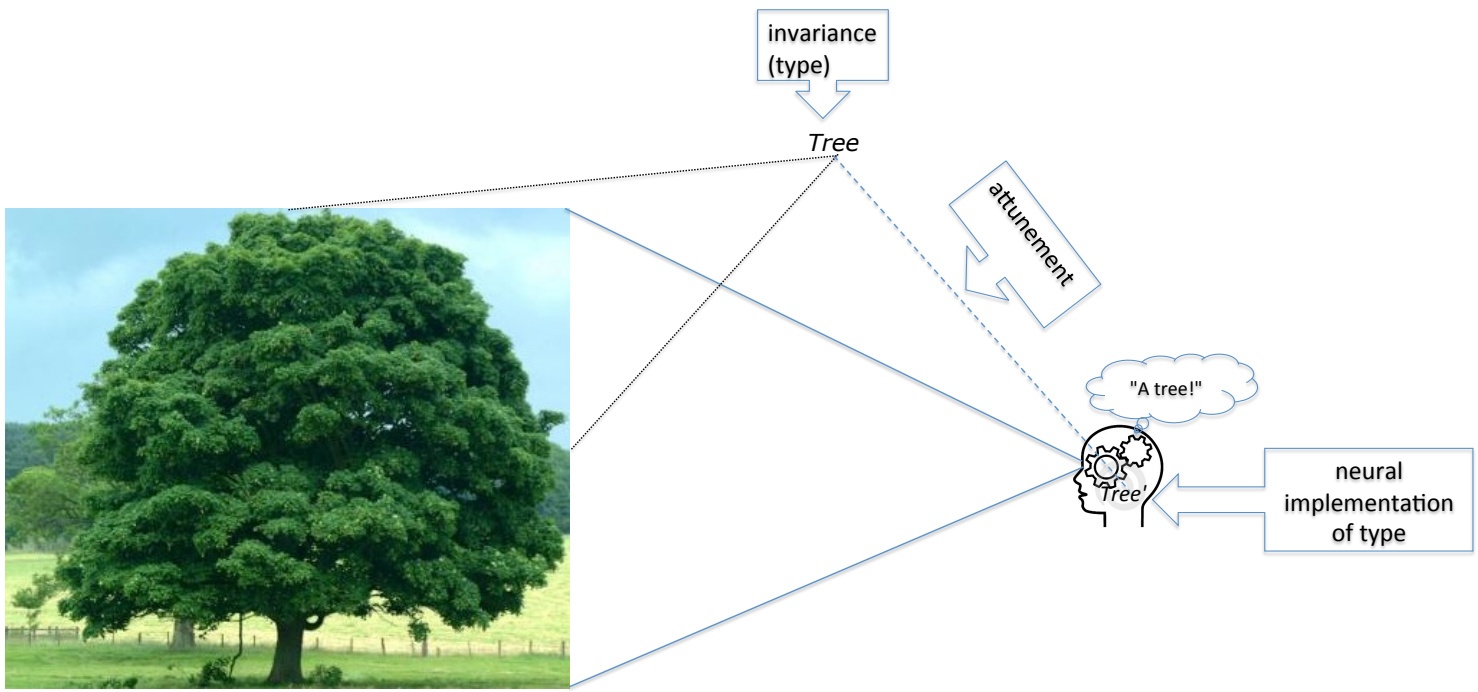

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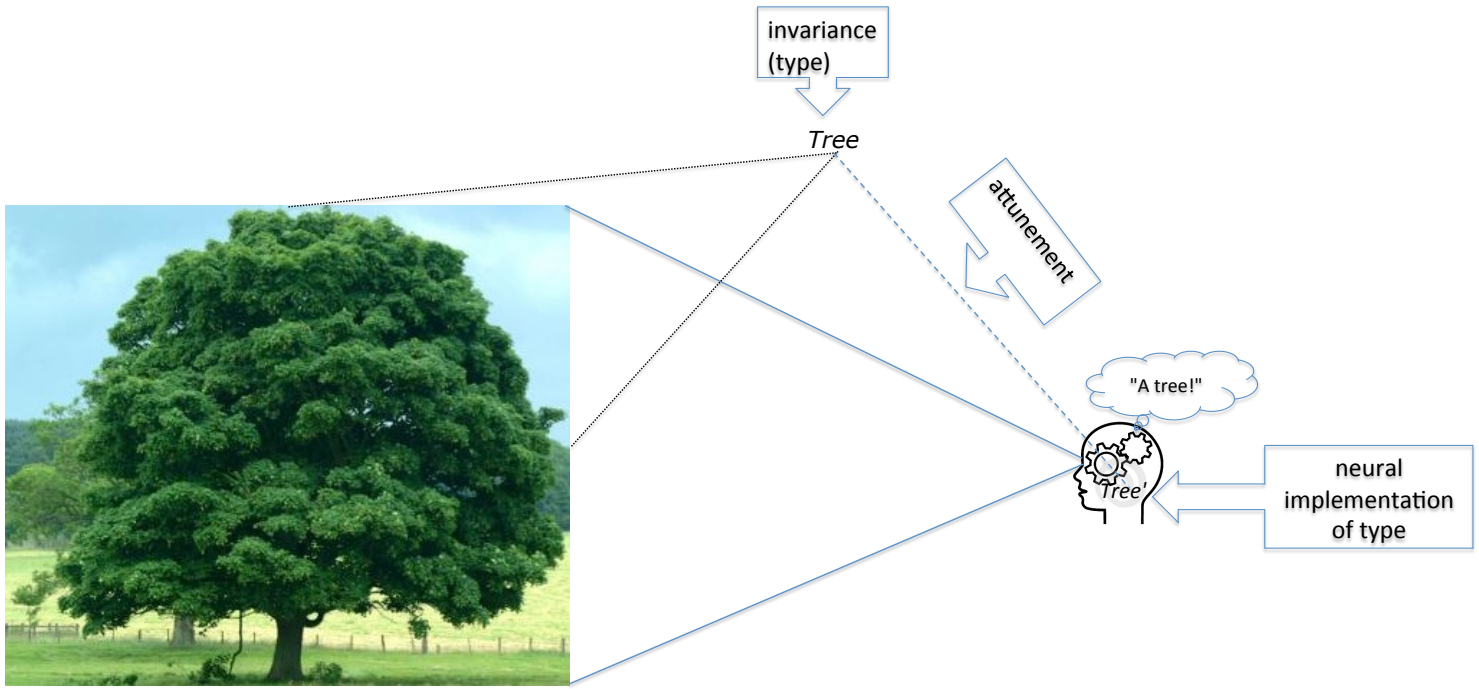

Gibson (1986); Barwise and Perry (1983)

Outline

TTR: Type theory with records I

- The most recent published reference for the details is Cooper (2012)
- an overview with some details Cooper and Ginzburg (2015), see also `https://sites.google.com/site/semttrgbg/schedule` for lectures on youtube based on this material
- Also Cooper (2005a) for an earlier detailed treatment, Cooper (2005b) for relation to various semantic theories and Cooper (2017) for some linguistic motivation.
- `https://sites.google.com/site/typetheorywithrecords/drafts` for a book manuscript in (slow) progress, daily dump on `https://github.com/robincooper/ttl/blob/master/ttl.pdf`

TTR: Type theory with records II

- In general TTR references can be found at `https://sites.google.com/site/typetheorywithrecords/publications`
- implementation `PyTTR` on `https://github.com/GU-CLASP/pyttr`

Rich type theory

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- *rich type theories* (e.g. Martin-Löf, 1984) provide a more general collection of types, e.g. in our type theory, categories of objects such as *Tree*, types of situations such as *Hugging of a dog by a boy*
- two fundamental questions when characterizing a type theory:
  - what types are there?
  - for any type, what are the objects of that type?

Judgement

- (An agent judges that) object a is of type T.
- $a : T$
- in `pyttr`

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Witness conditions for types

- witness conditions for types can be external to type theory, for example, classifiers
- Arild Matsson's MLT thesis (`https://github.com/arildm/imagettr-thesis`)
- in `pyttr`

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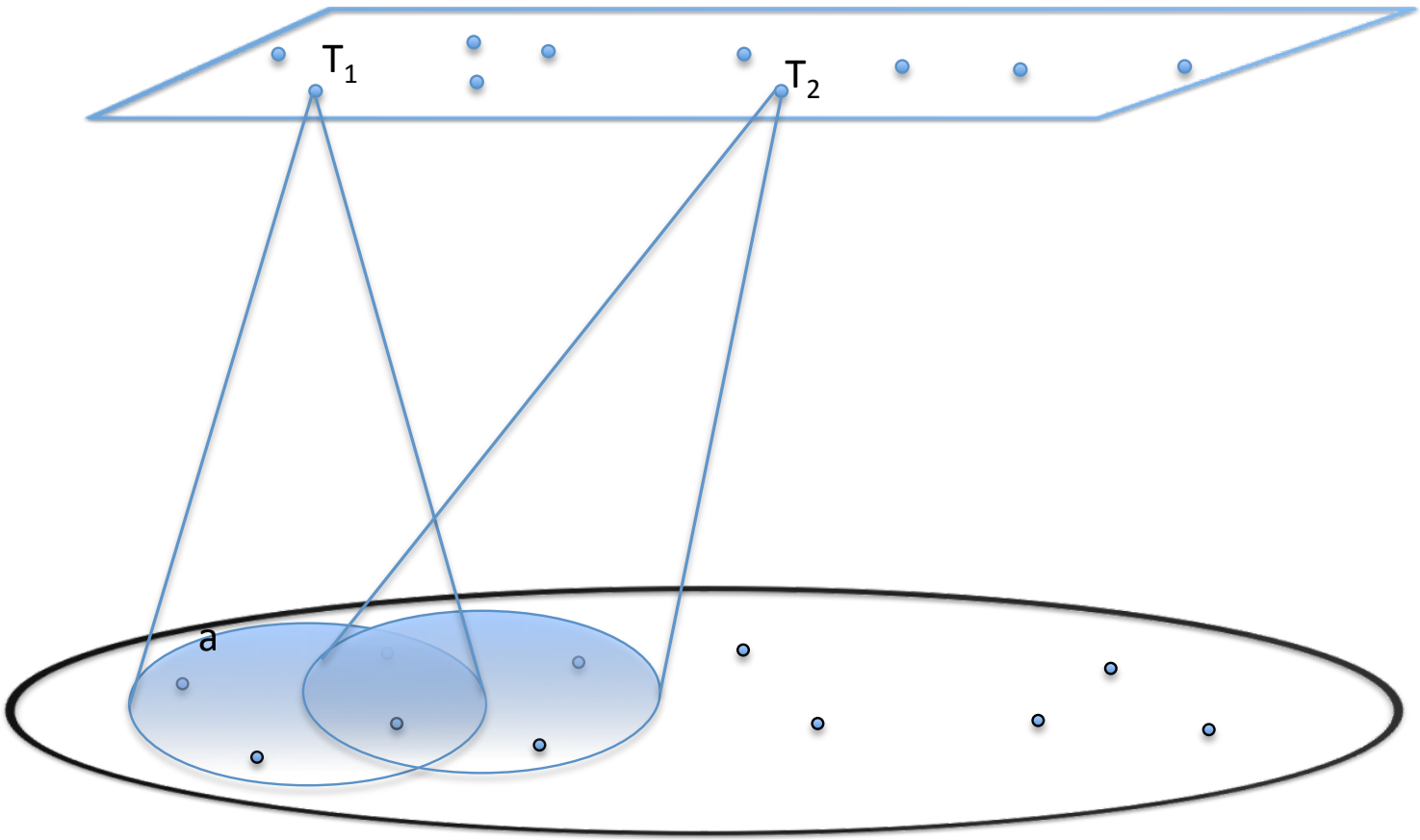
$a : T_1$



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- one kind of complex type is *ptype*, types which are constructed from predicates and objects used as arguments to the predicate
- another kind of complex type is *record type*, types which consist of a collection of types indexed by labels

Why is structure important?

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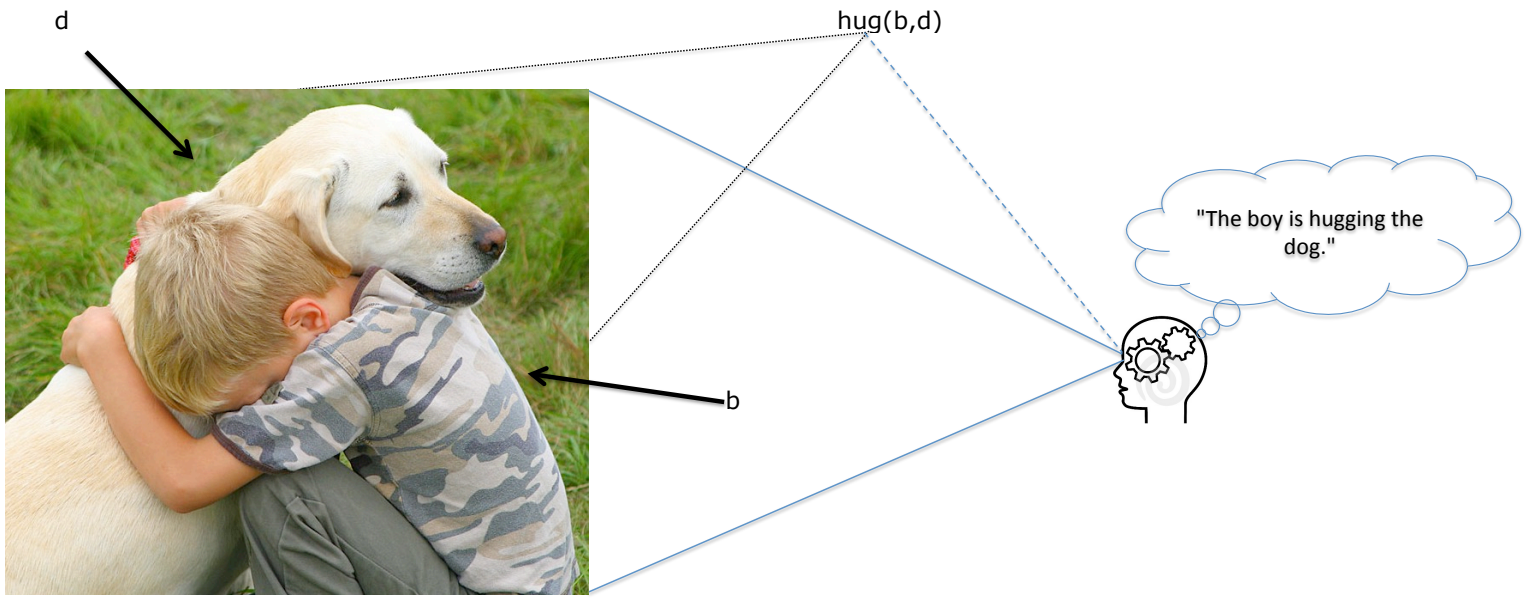
- allows us to find parts within a whole (e.g. in clarification)
- allows us to modify by adding or removing a part (e.g. in learning new meanings or coordinating meaning with your dialogue partner)

Seeing a hugging event



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- We might also want to include time intervals and locations as part of the arities of these predicates

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- in `pyttr`

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- in `pyttr`

Witness conditions associated with ptypes

- in any situation, a is to the left of b iff b is to the right of a
- $s : \text{left}(a, b) \Leftrightarrow s : \text{right}(b, a)$
- in `pyttr`

Are ptypes the only types of situations?

- suppose b is Bill, a boy and d is Dinah, a dog
- we have allowed ourselves the ptype hug(b,d), the type of situation where Bill hugs Dinah
- but we have not allowed ourselves the type of "boy hugs dog" situations corresponding to *a boy hugs a dog*
- there are a number of ways to construct such types in rich type theories – we use *record types*

A boy hugs a dog

Record type – "a collection of labelled types"

$$\begin{bmatrix} x & : & \mathit{Ind} \\ c_{boy} & : & boy(x) \\ y & : & \mathit{Ind} \\ c_{dog} & : & dog(y) \\ e & : & hug(x,y) \end{bmatrix}$$

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Record type – "a collection of labelled types"
. . . not quite because of dependencies

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The official notation

$$\left[\begin{array}{lcl} \mathsf{x} & : & \mathit{Ind} \\ \mathsf{c}_{\mathrm{boy}} & : & \langle \lambda v : \mathit{Ind}(\mathsf{boy}(v)), \langle \mathsf{x} \rangle \rangle, \\ \mathsf{y} & : & \mathit{Ind} \\ \mathsf{c}_{\mathrm{dog}} & : & \langle \lambda v : \mathit{Ind}(\mathsf{dog}(v)), \langle \mathsf{y} \rangle \rangle \\ \mathsf{e} & : & \langle \lambda v_1 : \mathit{Ind}(\lambda v_2 : \mathit{Ind}(\mathsf{hug}(v_1, v_2))), \\ & & \quad \langle \mathsf{x}, \mathsf{y} \rangle \rangle \end{array}\right]$$

A record of type *a boy hugs a dog*

$$\begin{bmatrix} \mathsf{x} & = & a \\ \mathsf{c}_{\mathrm{boy}} & = & s_1 \\ \mathsf{y} & = & b \\ \mathsf{c}_{\mathrm{dog}} & = & s_2 \\ \mathsf{e} & = & s_3 \end{bmatrix}$$

where: $a : \mathit{Ind}$
$s_1 : \mathsf{boy}(a)$
$b : \mathit{Ind}$
$s_2 : \mathsf{dog}(b)$
$s_3 : \mathsf{hug}(a,b)$

Two important facts about records

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- You can construct a record of a given type just in case there are objects of the types required by its fields – i.e. the labelling is arbitrary
- A record of a given type may contain more fields than required by the type – this record also belongs to a subtype of the type where the extra fields are added

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- discourse representation structures
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- frames (as in frame semantics and FrameNet)

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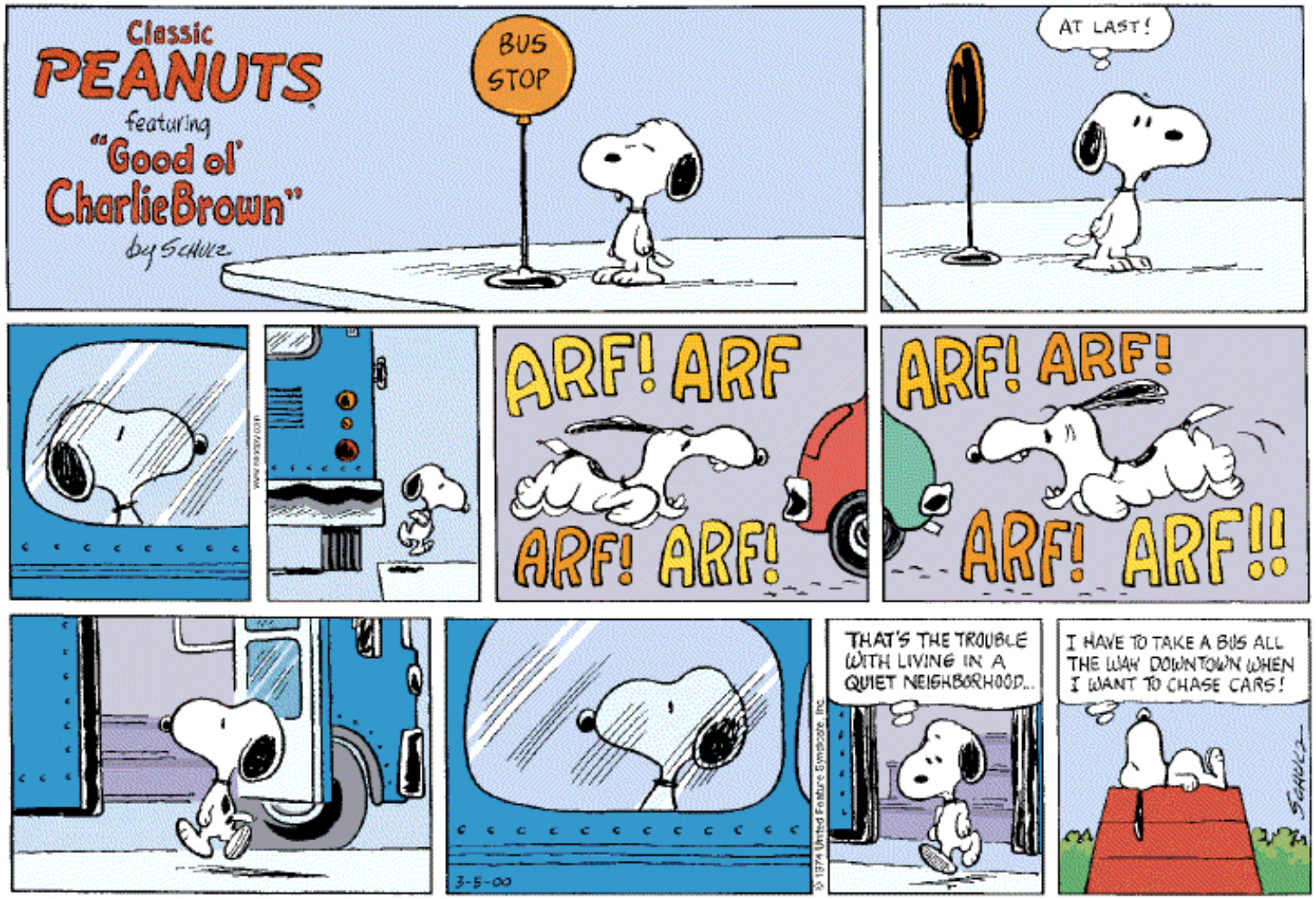
Outline

Fernando's string theory



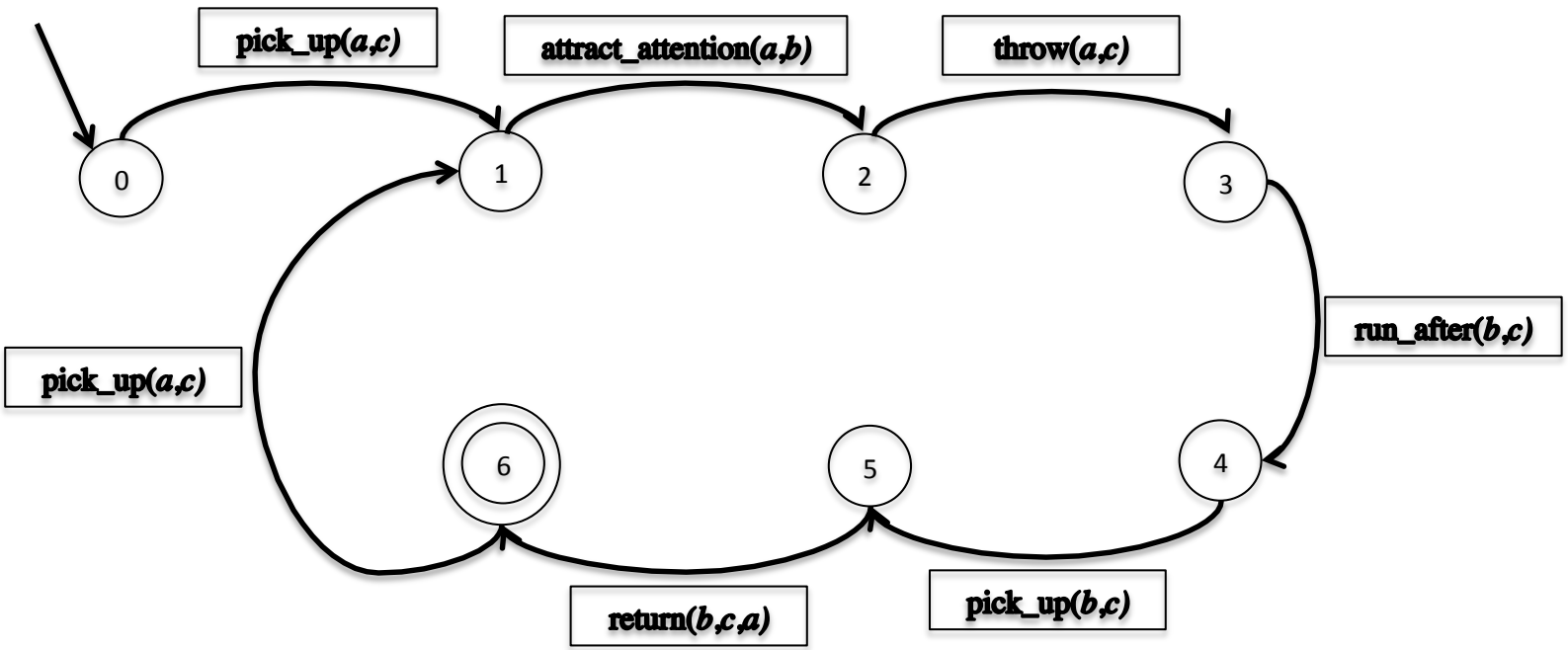
Some references to Fernando's work

Fernando (2004, 2006, 2008, 2009, 2015)

Regular types

1. if T_1, $T_2 \in$ **Type**, then $T_1 ^\frown T_2 \in$ **Type**
   $a : T_1 ^\frown T_2$ iff $a = x ^\frown y$, $x : T_1$ and $y : T_2$
2. if $T \in$ **Type** then $T^+ \in$ **Type**.
   $a : T^+$ iff $a = x_1 ^\frown \ldots ^\frown x_n$, $n > 0$ and for i, $1 \leq i \leq n$, $x_i : T$
   ...

A game of fetch



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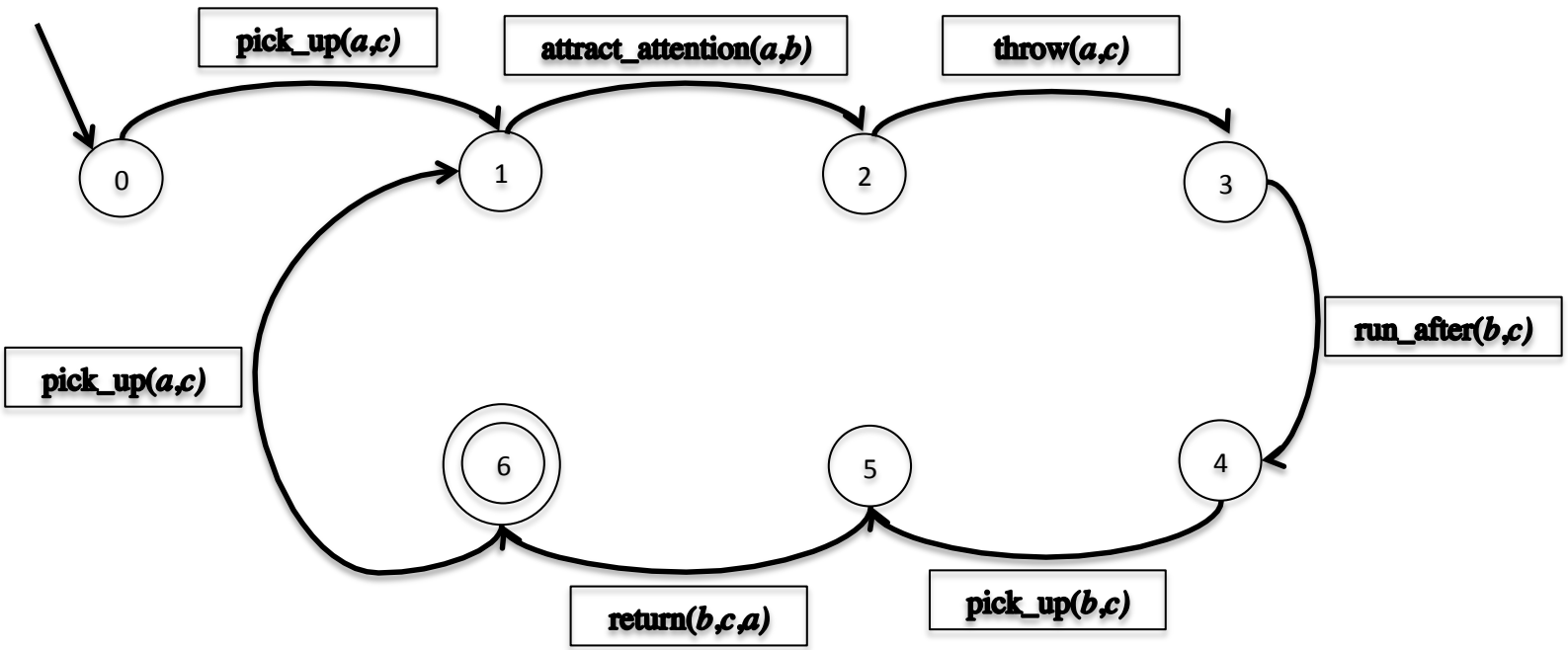

$$(\text{pick\_up}(a,c)^\frown\text{attract\_attention}(a,b)^\frown\text{throw}(a,c)^\frown\text{run\_after}(b,c)^\frown \text{pick\_up}(b,c)^\frown\text{return}(b,c,a))^+$$

Outline

Partiality of event perception

- Do not need to observe all the frames in an event
- Suffices to observe enough to uniquely identify event types agent has in its resources

Inferring an event type from a partial observation

$$\lambda r{:}\left[\begin{array}{l} \mathsf{x}{:}\mathit{Ind} \\ \mathsf{c}_{\mathrm{human}}{:}\mathsf{human}(\mathsf{x}) \\ \mathsf{y}{:}\mathit{Ind} \\ \mathsf{c}_{\mathrm{dog}}{:}\mathsf{dog}(\mathsf{y}) \\ \mathsf{z}{:}\mathit{Ind} \\ \mathsf{c}_{\mathrm{stick}}{:}\mathsf{stick}(\mathsf{z}) \\ \mathsf{e}{:}\mathsf{pick\_up}(\mathsf{x},\mathsf{z})^\frown\mathsf{attract\_attention}(\mathsf{x},\mathsf{y}) \end{array}\right]\left(\left[\mathsf{e}{:}\mathsf{play\_fetch}(r.\mathsf{x},r.\mathsf{y})\right]\right)$$

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- a *dependent type*
- perceiving something and inferring the type of something not (yet) perceived from that perception
- we will see a number of other uses of dependent types, for example as the interpretation of verb phrases

in `pyttr`

Outline

Summary

- Type theory as a formal theory related to perception
- A basic introduction to TTR:
  - basic types (e.g. *Ind*)
  - ptypes (e.g. hug(Sam,Dinah))
  - models which supply objects of basic types and ptypes
  - record types
  - mentioned some of their linguistic applications
  - string types
  - strings of events rather than strings of symbols

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References to work on TTR are available on
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