Ling 3701H / Psych 3371H: Lecture Notes 2
Language and Thought

All semester, we'll discuss *how* people decode sentence meanings (at algorithmic level).

This presumes we know *what* sentence meanings are (at computational level).

Contents

2.1 What do sentences mean? (A short course on linguistic semantics)

2.1.1 Basic parts of meanings

We assume sentences are **propositions** – things that have **truth values** (type `t`): True or False.

- Declaratives (e.g. *Some nuts are toxic.*) are simple propositions. We use these in planning.
- Imperatives (e.g. *Get me a bucket!*) are also propositions: *Speaker wants a bucket.*
- Interrogatives (e.g. *Where is Spain?*) are also propositions: *Speaker want to know . . .*

These propositions may involve **entities** (type `e`):

- 'Count' entities (e.g. squirrels, nuts, etc.)
- Minimal parts (e.g. water molecules, infinitesimals of continuous measure of weight, etc.)
- Eventualities (e.g. that time that squirrel ate that nut, etc.)

  These are regions of time during which a predicate (see below) holds over its arguments.
- Numbers (e.g. 3, $\sqrt{3}$, etc.)

Relationships between these entities may involve **functions** (like on a spreadsheet or calculator):

- Predicates (e.g. Eating) are functions from entity arguments x, y to truth values: Eating $x\ y$
  - Some predicates (e.g. $>$, $=$) are written *between* arguments: $x > y$, $x = y$
  - Some (e.g. Eating, BeingANut) are written *before* arguments: Eating $x\ y$, BeingANut x
  - Predicate functions have type: `e → t`, or `e → e → t`, or `e → e → e → t`, etc.
- Cardinality is a function from a predicate function P to an entity (number): $|P|$
  - Takes a function from entities to truth values, runs on all entities in discourse, counts trues.
  - The cardinality function has type: `(e → t) → e`
- Operators (e.g. $/$) are functions from entities (numbers) x, y to other entities (numbers): $x\ /\ y$
  - Operator functions have type: `e → e`, or `e → e → e`
- Connectives (e.g. $\wedge$) are functions from truth values t, u to other truth values: $t \wedge u$
  - Connective functions have type: `t → t`, or `t → t → t`

2.1.2 Lambda calculus notation

These relationships may be described using **lambda calculus** notation:

- Apply a function (type $\alpha \rightarrow \beta$) to an adjacent argument (type α) to get a result (type β):

  BeingOdd 3 (this means *three is odd*)

- Abstract (create) a function (type $\alpha \rightarrow \beta$) by writing a lambda for input (α) before output (β):

  λ_x BeingANut $x \wedge$ BeingToxic x (this means *toxic nuts*)

2.1.3 Quantifiers and other derived meanings

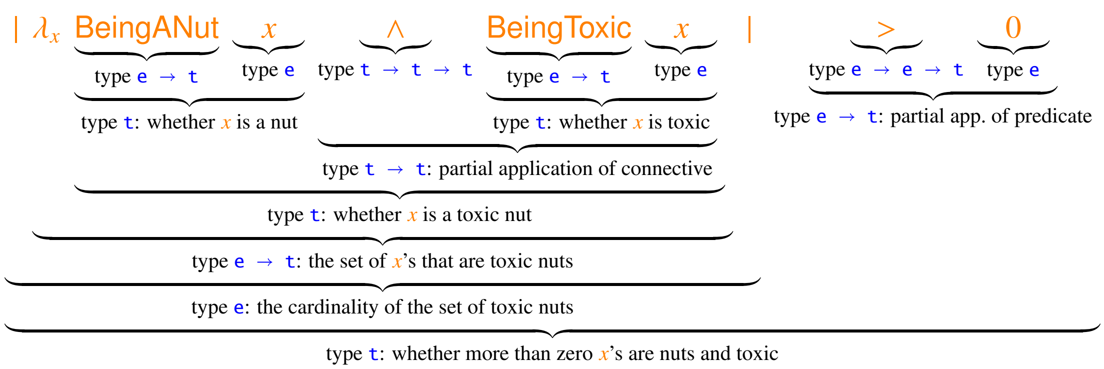
For example, we may define cardinal quantifiers like Some or No using the following expressions:

(Some $R\ S$) if and only if $(|\lambda_x\ R\ x \wedge S\ x| > 0)$ (this means *some R are S*)

(No $R\ S$) if and only if $(|\lambda_x\ R\ x \wedge S\ x| = 0)$ (this means *no R are S*)

Note these quantifiers take two predicates as arguments, so type is: `(e → t) → (e → t) → t`

Here are types and descriptions of the results of each abstraction and application in this expression:



We may also define predicative quantifiers like All or Most using the following expressions:

$$(\textsf{All}\ R\ S) \text{ if and only if } (|\lambda_x\ R\ x \land S\ \ x|\ /\ |\lambda_x\ R\ x| = 1.0) \qquad \text{(this means } \textit{all R are S}\text{)}$$

$$(\textsf{Most}\ R\ S) \text{ if and only if } (|\lambda_x\ R\ x \land S\ \ x|\ /\ |\lambda_x\ R\ x| > 0.5) \qquad \text{(this means } \textit{most R are S}\text{)}$$

(We may additionally assume that the ratio of two infinite sets is defined as the ratio of the intersection of each set with a randomly sampled set of entities as the sample size approaches infinity.)

If we assume some predicates have eventualities as arguments, these can be quantified as well:

$$\textsf{Most}\ (\lambda_x\ \textsf{BeingASeed}\ x)\ (\lambda_x\ \textsf{No}\ (\lambda_e\ \textsf{BeingAnEvent}\ e)\ (\lambda_e\ \textsf{Growing}\ e\ x)) \qquad (\textit{Most seeds never grow.})$$

Predicative quantifiers define **conditional probabilities** – a basis for probabilistic reasoning.

2.1.4 Practice

For the following expression:

$$|\ \lambda_x\ \textsf{BeingANut}\ x \land \textsf{BeingToxic}\ x\ |\ \ /\ \ |\ \lambda_x\ \textsf{BeingANut}\ x\ |\ \ >\ \ 0.5$$

1. Draw circles or braces around each abstraction or application.
2. Describe and identify the type of the result of each abstraction or application.

2.1.5 More Practice

Using only predicates, cardinalities, operators, connectives and quantifiers as described above, write a lambda calculus meaning for the sentence: *Most numbers are greater than -5.*

2.2 Is language the same as thought?

We seem to think/plan complex ideas using sentences. Is language just vocalized thought?

No, many animals have complex ideas (plans), but very few have complex language.

2.2.1 Many animals have complex ideas (plans)

Clayton, Bussey & Dickinson – scrub jays cache food based on where they might be hungry.

Nicholas Mulcahy & Josep Call – bonobos and orangutans choose, carry away, and return w. tools.

2.2.2 Few animals have complex language

Many animals have natural communicative abilities:

- fireflies,bees – communicate location of self/nectar
- birds,whales – communicate fitness to potential mates
- cats,dolphins – communicate a search for a specific animal by name
- diana monkey – communicate alarm calls

Some can be trained to have human-like communicative abilities:

- Clever Hans (horse) – pretend to add (recognize expectation to end count)
- Dog that knows 1000 words – knows 1000 words (symbolic)
- Alex the parrot – identify items by shape and color (classify)
- Anonymous finches – recognize recursion in birdsong
- Vicki the chimp – recognize, produce (a few) spoken utterances
- Washoe, Nim Chimpsky, Koko (gorilla) – produce sign language
- Panpanzee, Panbanisha (bonobo) – from infancy
- Akeakamai the dolphin – word order, argument structure

Tomasello – most animals don't *collaborate*; no need for complex structure

2.3 Evolution of language

We may conclude that language evolved after complex ideas/planning/thought.

But how? It depends on whom you ask…

- nativist – language is a specialized organ in the brain that other species don't have

- anti-nativist – language is how any cooperative species with complex ideas communicate

Some anthropological history:

- 8-5 million y.a.: human, chimp, bonobo common ancestor
  - tool use inherited to humans, chimps, ..., but no language
- 2 million y.a.: start of ice age, homo erectus emerges
  - fire (hardened clay dated 1.5 mil y.a.),
  - clothing
- 1 million y.a.: homo heidelbergensis emerges
  - neanderthals diverge (until 30,000 y.a.): high larynx, tools, burials, communication?
- 200,000-100,000 y.a.: homo sapiens emerges
  - humans nearly wiped out? (Spencer Wells DNA stats: population as low as 2000)
  - lower larynx, innervation for breathing control
- 40,000 y.a.: particularly cold ice age, 'upper paleolithic revolution'
  - organized settlements: campfire, storage pit, in narrow valley for hunting
  - tools – indicate specialization of skills
  - built boats/rafts to colonize New Guinea and Australia
  - cave paintings – indicate reference (it's paint, and it's a deer)
  - humans probably had language by this time

2.4 Activity: evidence and how it counts

List evidence for and against the nativist hypothesis, and explain how it counts as evidence.

2.5 Instinctual properties of language

Some evidence that language acquisition is biological:

- spontaneous: children learn pidgins as creoles (Sengas, NSL)
- critical period for syntax:
  - Jim:1;6 & Glen:3;9 – hearing of deaf parents: no syntax, but learned ok,
  - Genie:13yrs – imprisoned during childhood, syntax deficits
- SLI from FOXP2 gene: assoc. w. morphology & other fast sequencing

2.6 A Taxonomy of Cognition

We may therefore infer the following distinctions:

- **mental / cognitive states:** thoughts, basic ideas, e.g. hunger
  - feelings, percepts, memories, eventualities, plans, . . .
  - **propositions / complex ideas / plans:** thoughts that can be true or false
- **communication / signals:** transmit information, w. **form** and **meaning**
  - indices: pointers (firefly lights, bee dances, . . .)
  - icons: resemblances (photos, diagrams, art, . . .)
  - symbols: signals w. known, shared meanings (monkey alarms, names)
  - **languages:** signal ('sign') systems with indices, icons, symbols, and (Hockett) . . .
    - semanticity: signs have meanings
    - arbitrariness: signs just have to be different from each other
    - discreteness: form consists of clusters/classes (excludes bee, firefly)
    - displacement: meanings may refer to place/time other than here/now
    - duality of patterning: signs perceived as phonemes and words
    - generativity: signs, meanings can be composed to make new thoughts