A Cognitive Architecture for Communicative Repair Strategies

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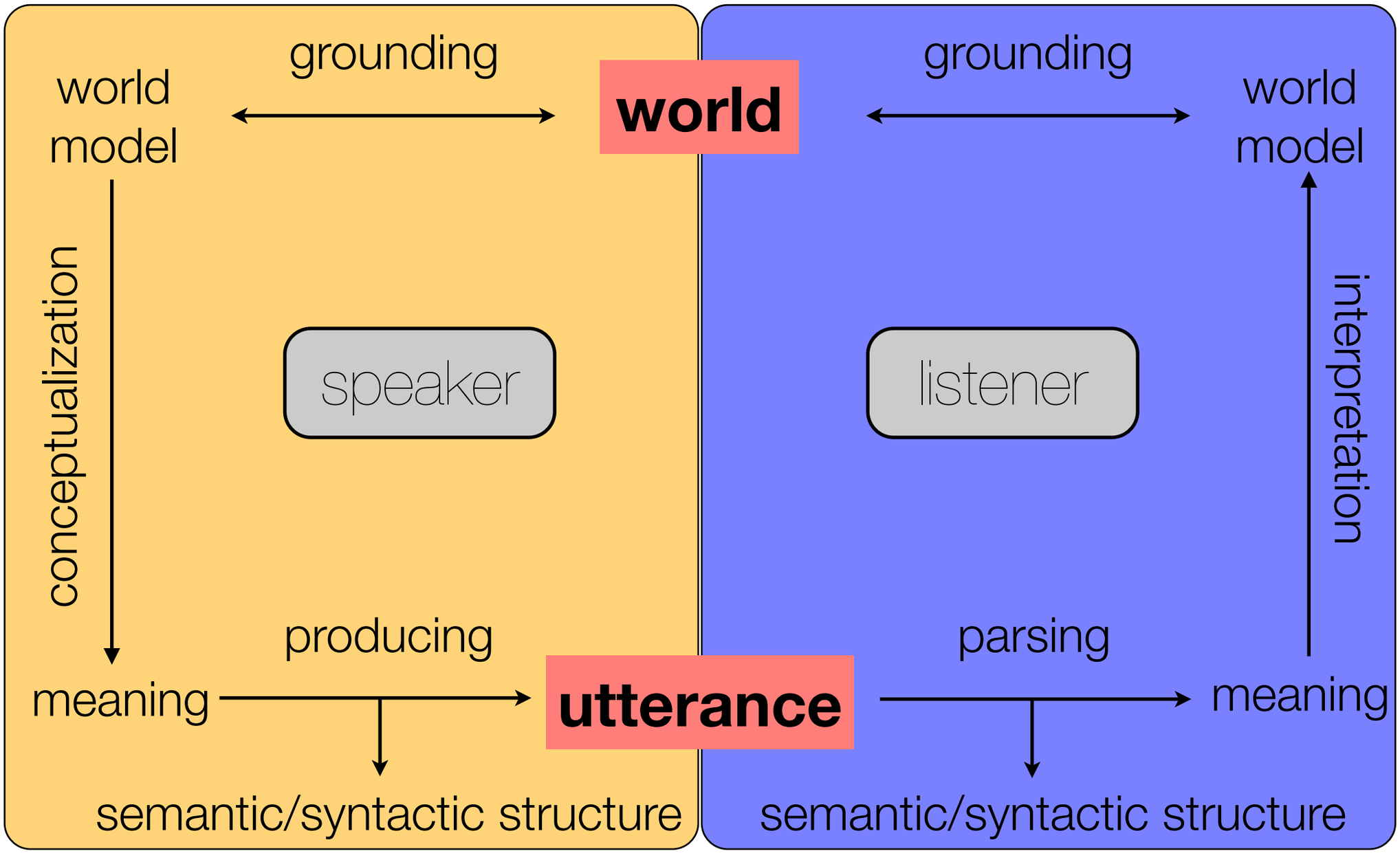
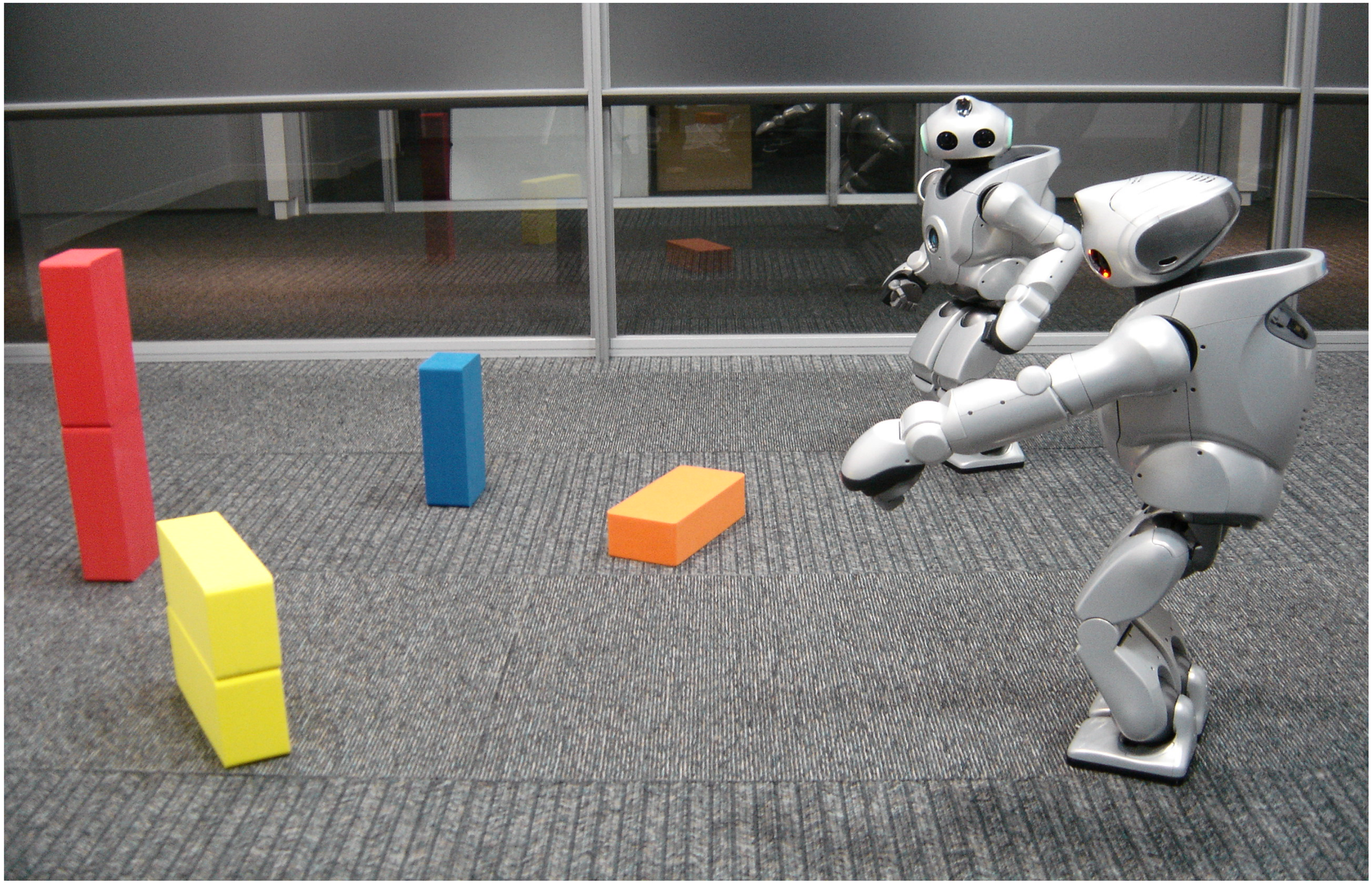
Our Research is a Team Effort

Our Approach

- Make detailed operational models of all information processing that goes into language processing + language learning
  - Even if it is only for limited domains
- Simulate language evolution in populations of agents playing language games
- Use robots to address issues of sensori-motor embodiment
  - Grounded semantics
  - Influence of environment on emergent language

Semiotic Cycle



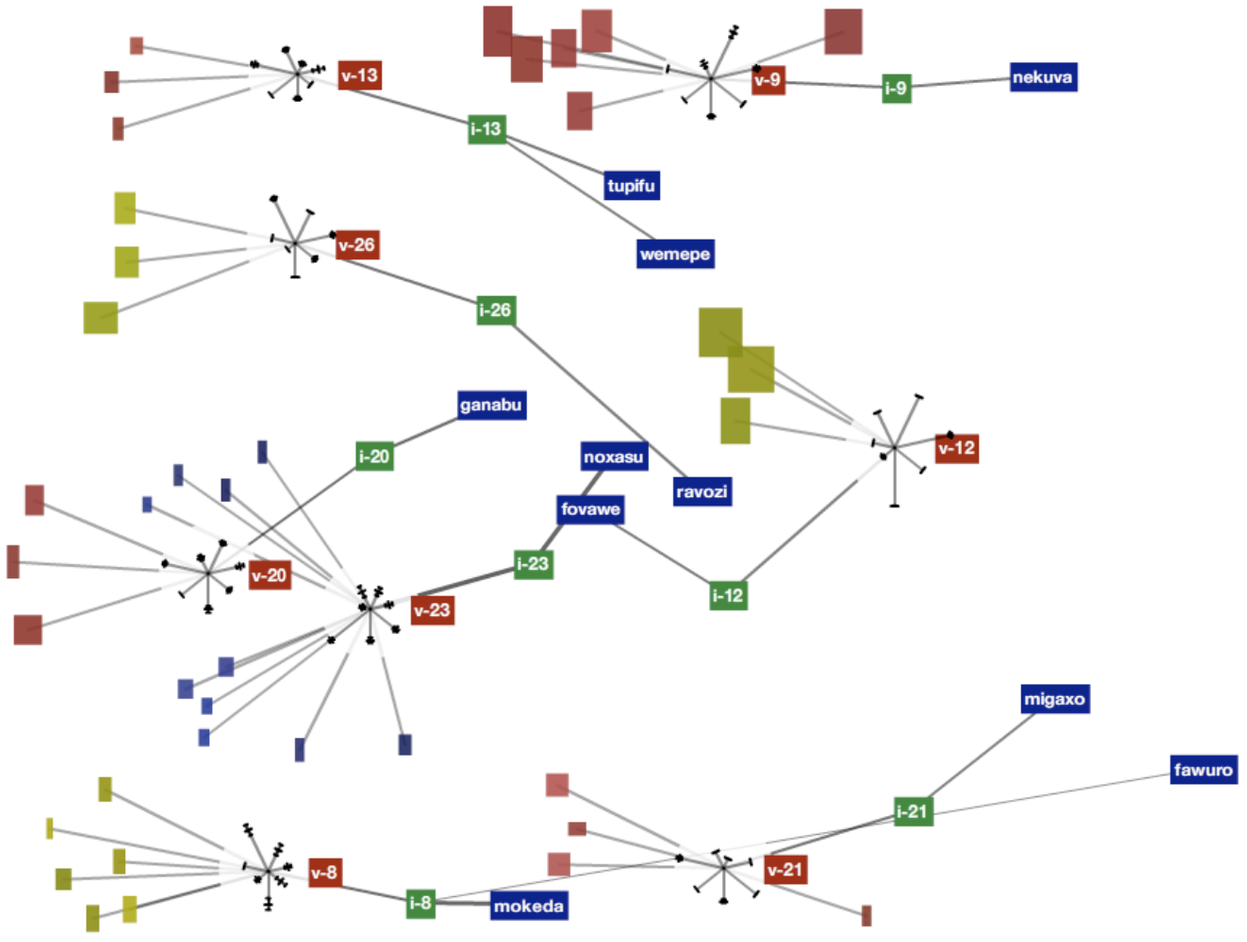


Example of a Language Game

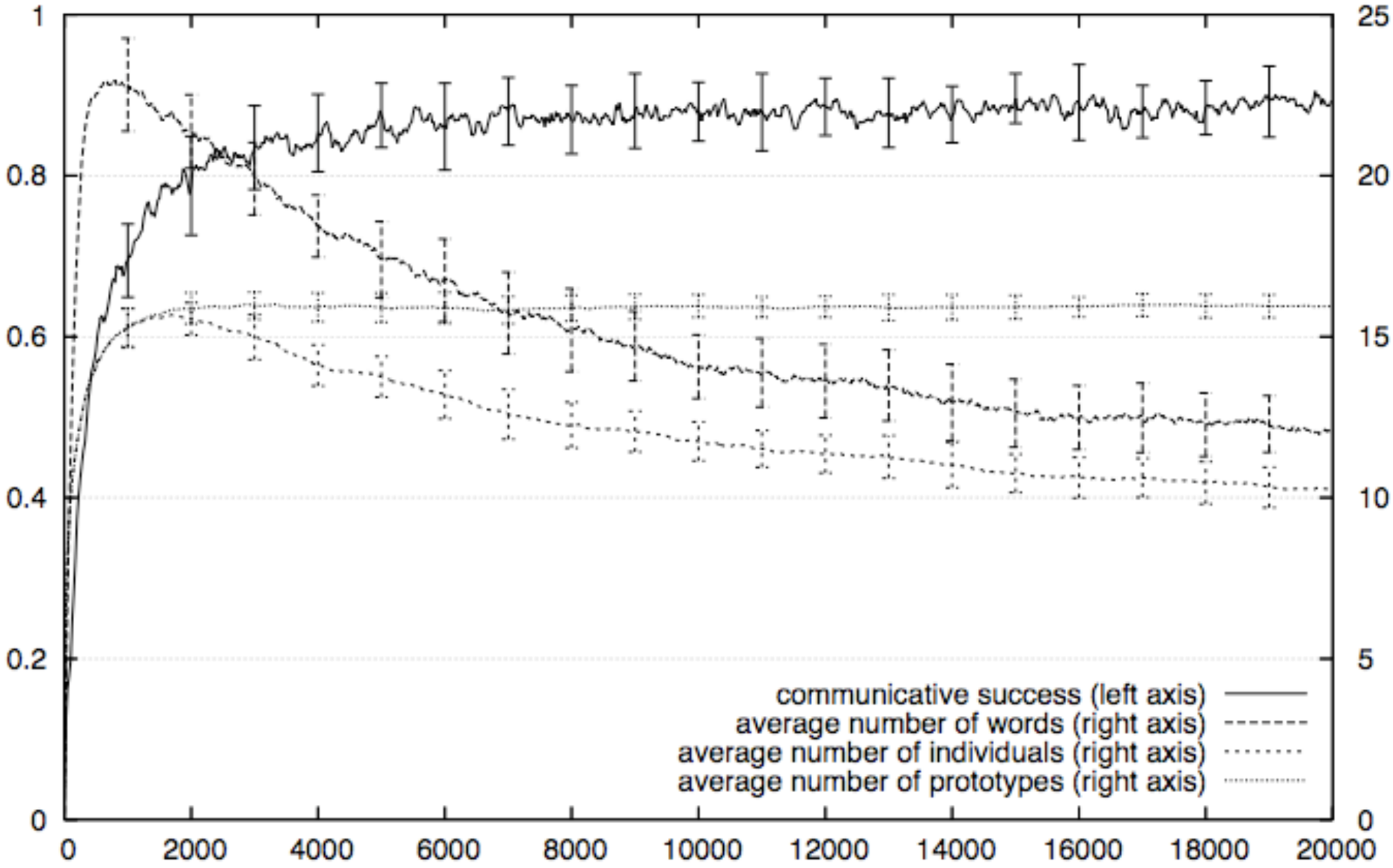
The Grounded Naming Game

Steels, Luc and Michael Spranger (2012). The Grounded Naming Game. In: Luc Steels (ed.) *Experiments in Cultural Language Evolution*. John Benjamins: Amsterdam.

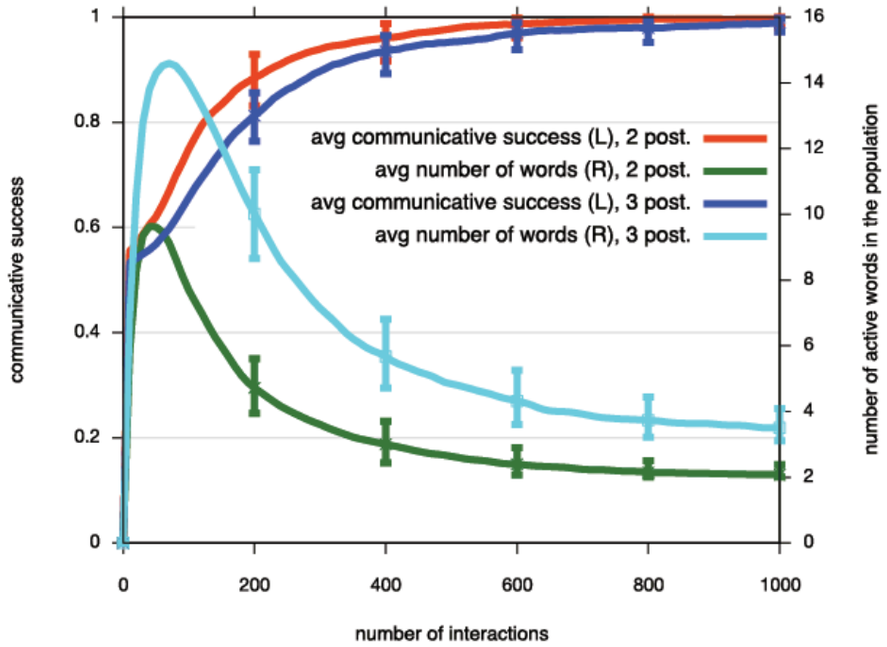
Semiotic Network

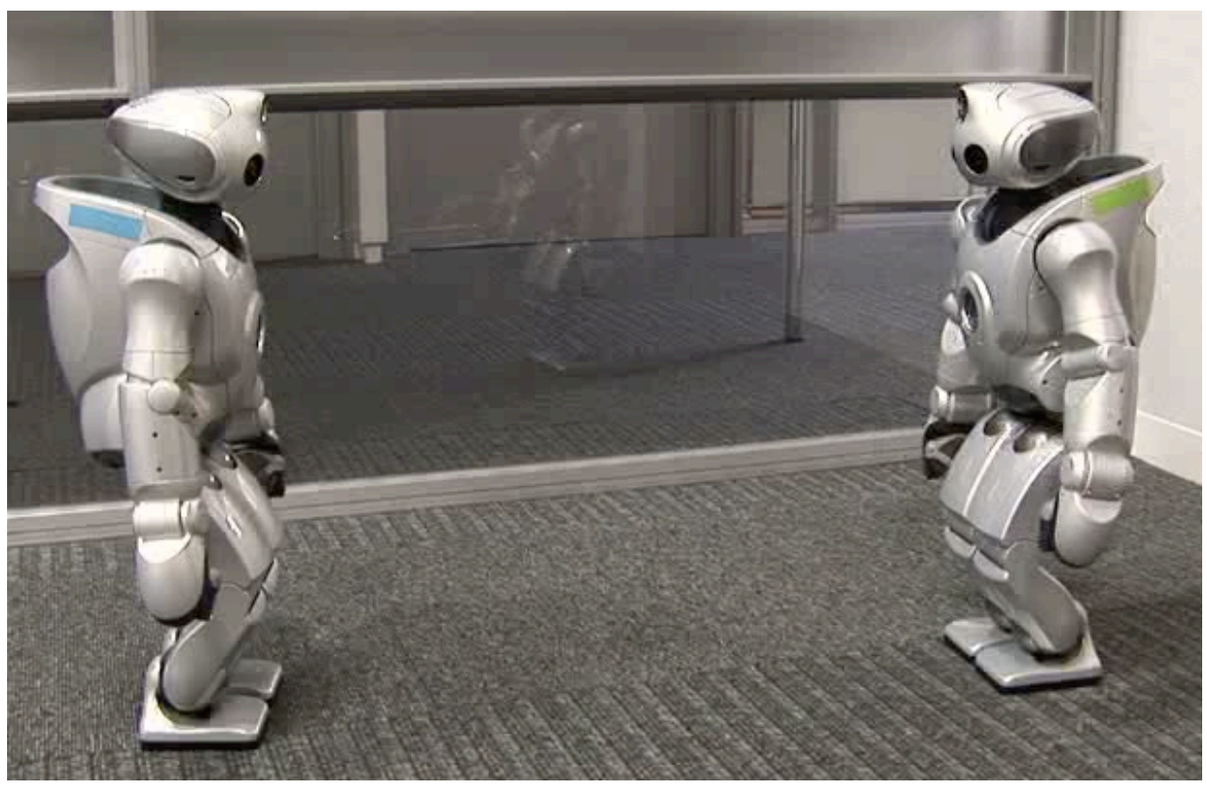


Results after 20 000 games



Action Games

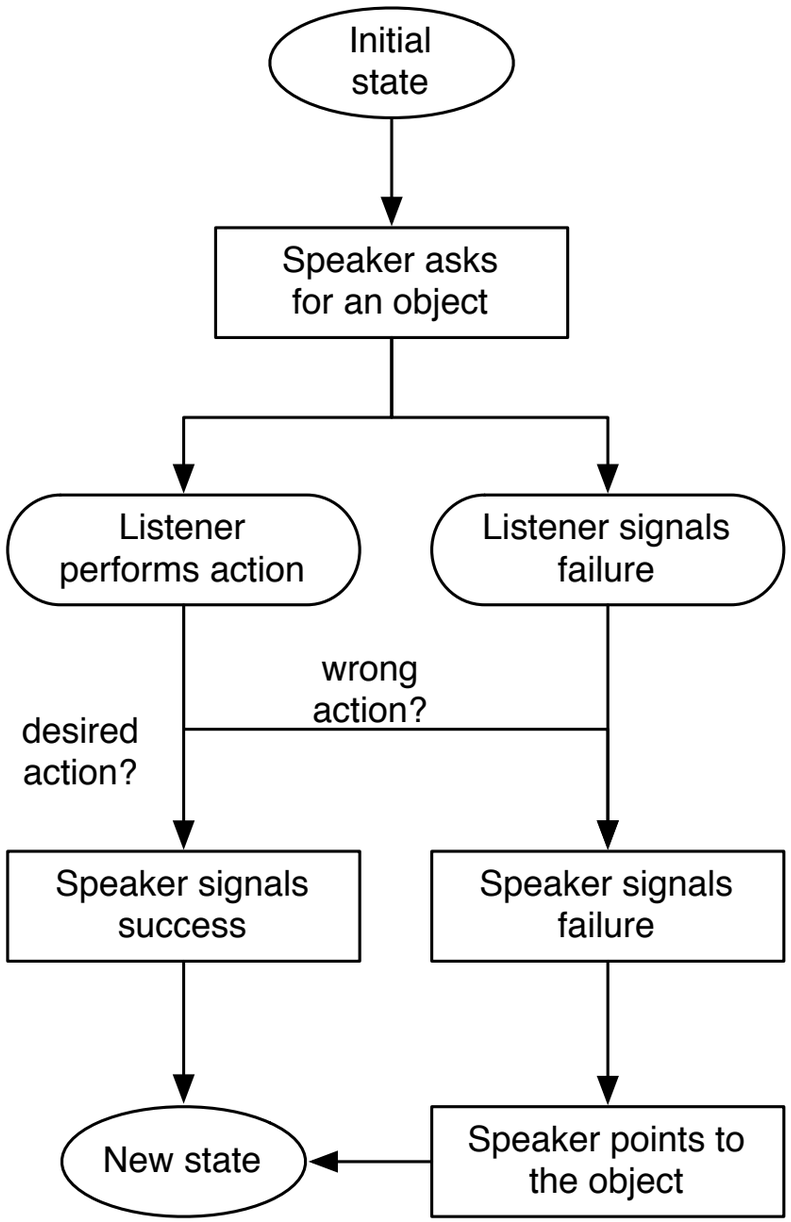




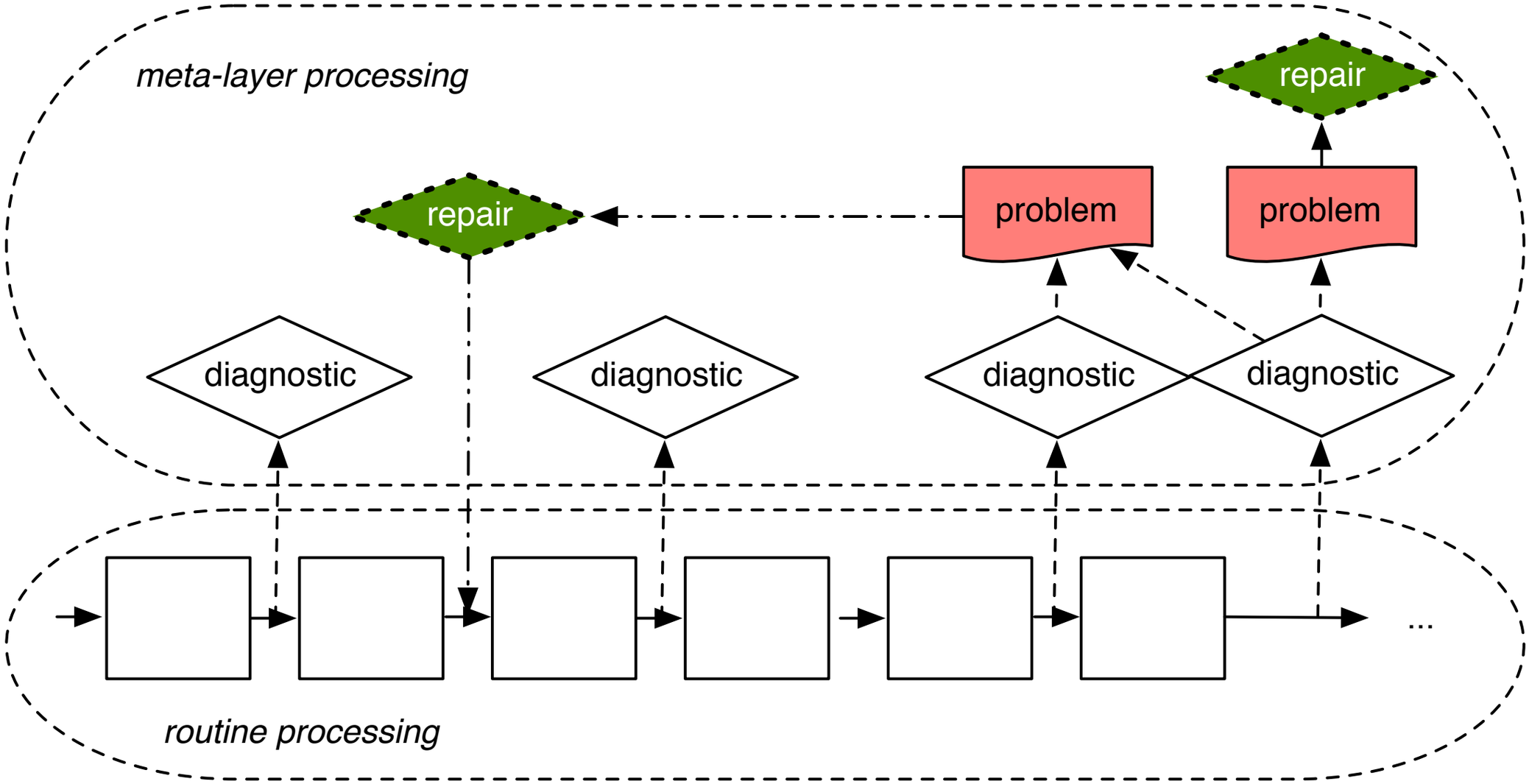
Steels Luc and Michael Spranger (2008). Can body language shape body image? Artificial Life XI. The MIT Press, Cambridge Ma. pp. 577-584.

When a game fails...

Example



- Father: Could you pass me the salmon, please?
- (The student hesitates and then reaches for the salt.)
- (The father shakes his head.)
- Father: No, I meant the salmon. (Points to the fish on a plate.)
- (The student puts the salt back and hands over the plate.)
- Father: Thank you.



A Reflective Architecture

Diagnostics and Repairs

Beuls Katrien, Remi van Trijp and Pieter Wellens (2012). A Reflective Architecture for Open-Ended Language Processing in Fluid Construction Grammar. In: Luc Steels (ed.) *Computational Issues in Fluid Construction Grammar*. Springer Verlag: Berlin.

Example Repair

- Student in example game passed the host father the salt instead of the salmon.
- Problem = unknown word
- “salt” closely resembles “salmon”
  - phonologically (syllable “sal”)
  - semantically (edible, present in shared context, graspable)

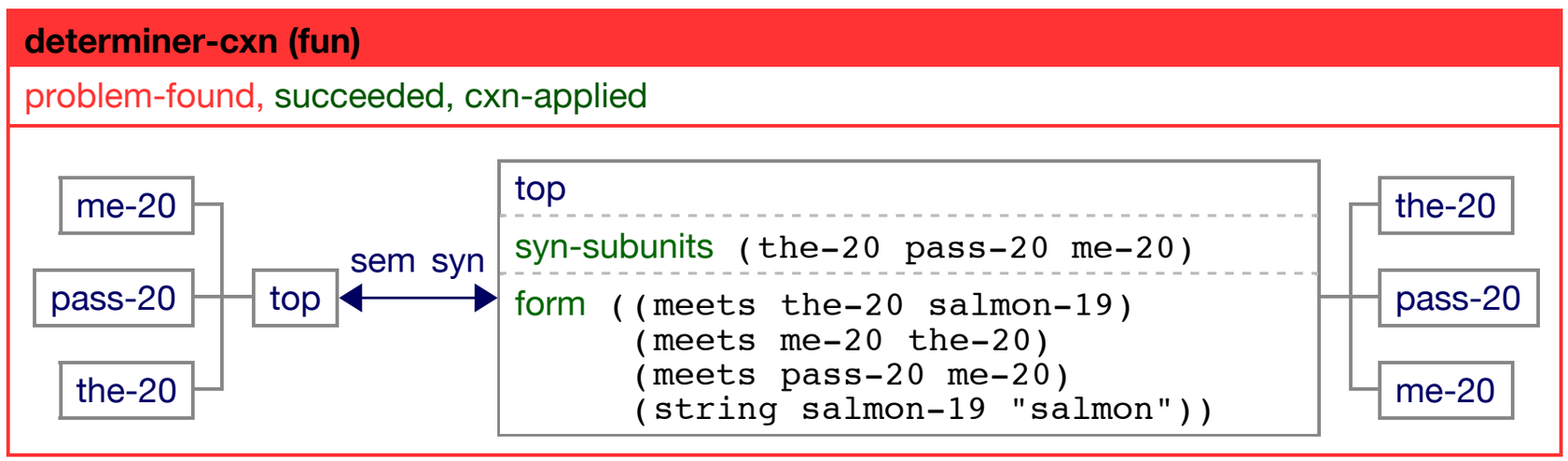
Diagnostic: Detect unknown word

diagnose-fcg (detect-unknown-word-in-fcg-search FCG-node)

```
When NODE is a LEAF then:
  let UNPROCESSED-STRINGS be the EXTRACTED-UNPROCESSED-STRINGS of FCG-NODE
     if UNPROCESSED-STRINGS contains a SINGLE-WORD
     then return an instance of UNKNOWN-WORD
               and set the slot-value of :WORD to SINGLE-WORD
     else return NIL
```

- When search node is a leaf and it contains unprocessed strings => create unknown word problem

- Unprocessed strings are words that cannot be retrieved from the current grammar of an agent



Repair: Retry with closest match

- Loop through all words in the current grammar and return the word that most closely resembles the unknown word based on its form.
- Similarity in terms of spelling and phonetic form.
- The unknown word is then replaced with the closest match in the input structure and parsing is restarted.
- Now, parsing succeeds and the agent passes the salt.
- However, the game FAILS since the wrong object was picked by the listener.

repair-fcg (retry-with-closest-match problem FCG-node)

```
Let UTTERANCE be the RENDERED LINGUISTIC STRUCTURE of FCG-NODE
and UNKNOWN-WORD be the :WORD slot in PROBLEM
and CLOSEST-MATCH be the UNKNOWN-WORD'S CLOSEST RELATED WORD in FCG-NODE-GRAMMAR
   if there is a CLOSEST-MATCH
   then return TRUE
      and let the REVISED-UTTERANCE be the UTTERANCE after the UNKNOWN-WORD
              has been REPLACED with CLOSEST-MATCH
       then RESTART SEARCH TREE with REVISED-UTTERANCE
   else return NIL
```

Generic Lexical Construction

- Never considered during routine processing
- Generic template:

```
(def-lex-cxn  generic-lexical-cxn

 (def-lex-skeleton  generic-lexical-cxn
  :meaning  (?unknown-meaning  ?set  ?context)
  :args  (?set  ?context)
  :string  ?unknown-string)

(def-lex-cat  generic-lexical-cxn
  :sem-cat  ?sem-cat
  :syn-cat  ?syn-cat))
```

- Template for salmon construction:

```
(def-lex-cxn  salmon-cxn
  :inherits-from  generic-lexical-cxn

  (def-lex-require  salmon-cxn
    :cxn-string  "salmon"))
```

New Construction after Pointing

- At the end of the game, the speaker points to the object he meant:

- The listener can now update the salmon construction with a meaning that he attributes to this object. This meaning can be expanded and modified in later interactions.

Conclusions

- Reflective processing architecture to capture that:
  - Language is open-ended
  - Same linguistic material is recruited in multiple ways (homonyms, word classes, etc.)
  - Speakers (and listeners) are not perfect
- Repairs of misunderstandings can help to establish common ground
- Future work:
  - Facilities for discourse marking and modality => development of a richer factual model
  - Emergence of language-specific diagnostics and repairs

References

- Steels, Luc, ed. (2012a). *Computational Issues in Fluid Construction Grammar*. Berlin: Springer Verlag.

- Steels, Luc, ed. (2012b). *Design Patterns in Fluid Construction Grammar*. Amsterdam: John Benjamins.

- Steels, Luc, ed. (2012c). *Experiments in Cultural Language Evolution*. Amsterdam: John Benjamins.

- Steels, Luc and Manfred Hild, ed. (2012). *Language Grounding in Robots*. New York: Springer Verlag.