

Interactive installation for collaborative creation of a language:

Active negotiation of new
linguistic conventions

William Schueller, Pierre-Yves Oudeyer

Social Convention?

- Arbitrary choice
(among equivalent options)
- Interest in agreeing with the group



Road side for driving



Greeting protocol



Electric plugs



Language

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- Potential conflicts
- **Dynamics?**



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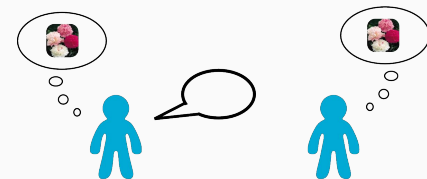


1	limite meridionale del tipo	<i>ortiga</i> «orticca» (-c- > -g-)
2		<i>sal</i> «sale» (caduta di -e)
3		<i>cavei</i> «capelli» (-p- > -v-)
4		<i>spala</i> «spallia» (-ll- > -l-)
5		<i>stir, stur</i> «scellino» (caduta della vocale protoni)
6		<i>pa</i> «pane»
7		<i>inci, inci</i> «oggi»
8	limite settentrionale del tipo	<i>ferraru</i> «fabbro»
9		<i>frate</i> «fratello»
10		<i>femmina</i> «donna»
11		<i>figlione</i> «mio figlio»
12		<i>tene le spalle larghe</i> «ha le spalle larghe»
13		<i>cusa</i> «coscia»
14		<i>lu cimice</i> «la cimice»
15		<i>fagu</i> «faggio»
16		<i>mondone</i> «monotone» (-nt- > -nd-)
17		<i>dienti</i> «denti» (metafonesi)
18		<i>acitu</i> «aceto» (metafonesi)

I numeri sono quelli dei puni d'inchiesta dell'A.I.S.



New word-meaning associations



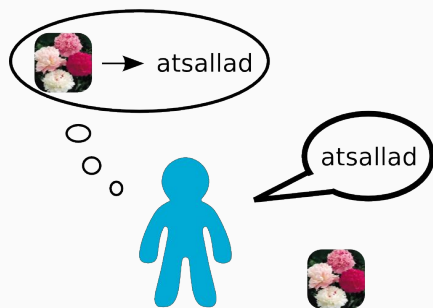
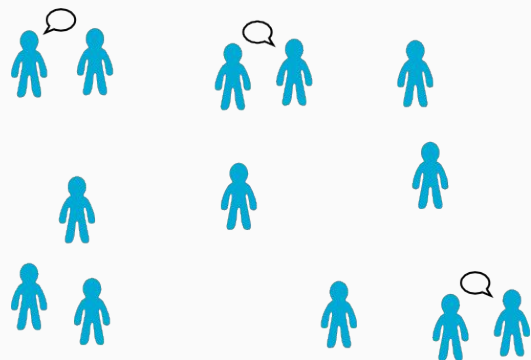
Competition between words for same meaning:
femmina/donna, pa/pane, acitu/aceto, ...

Language

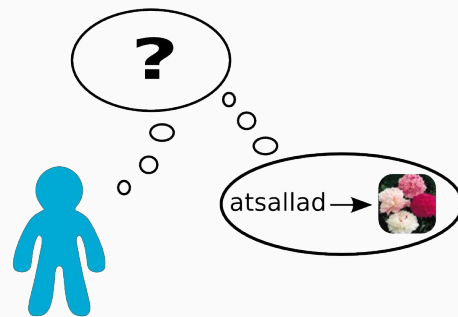
The Naming Game

- Multi-agent model
- No central control or information individuals per interaction)

(2



Speaker



Hearer



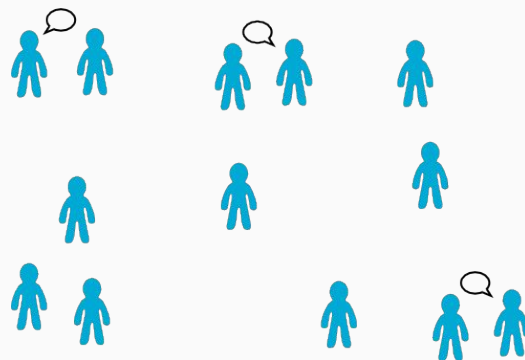
Origins: the Talking Heads Experiment (Luc Steels)

The Naming Game

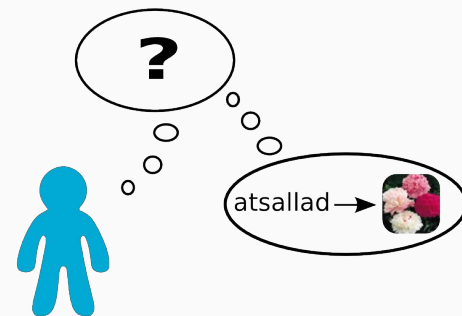
- Multi-agent model
- No central control or information individuals per interaction)

(2

Innovation: inventing new meaning-word associations



Speaker



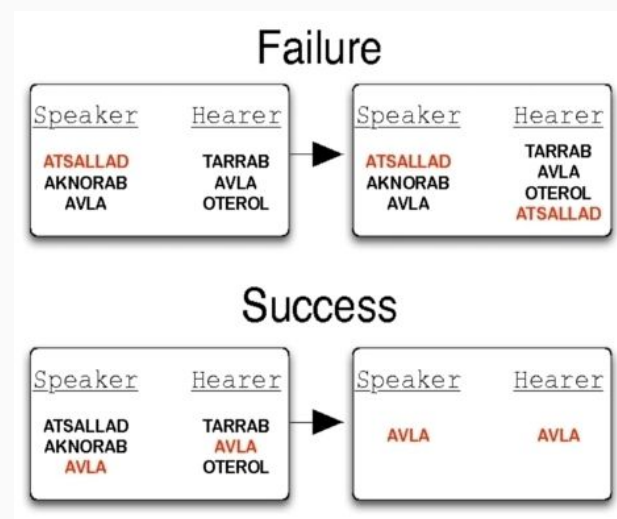
Hearer



Origins: the Talking Heads Experiment (Luc Steels)

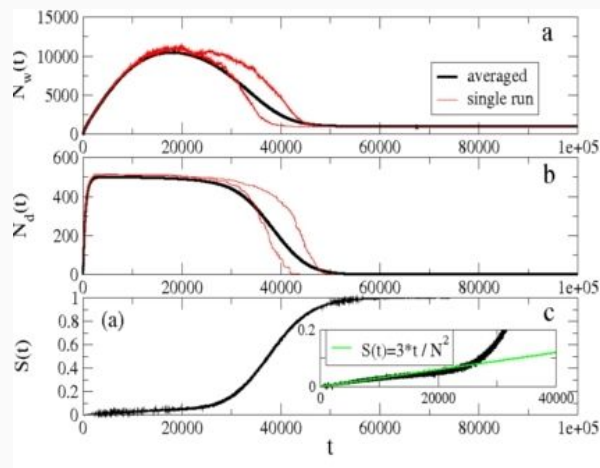
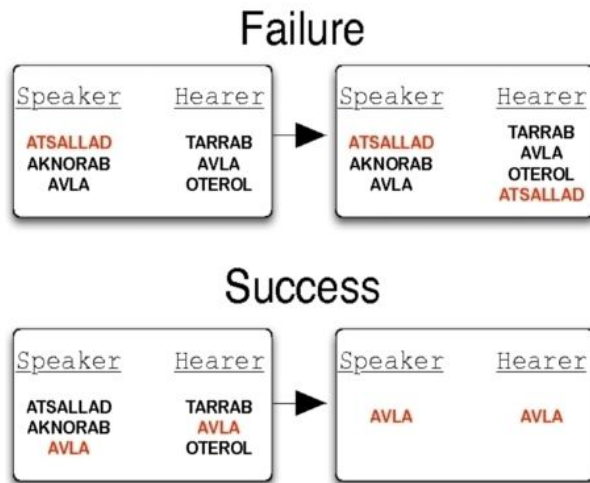
The Naming Game

- Multi-agent model
- No central control or information (2 individuals per interaction)
- Simple rules of update after interaction
- Dealing with synonymy



The Naming Game

- Multi-agent model
- No central control or information (2 individuals per interaction)
- Simple rules of update after interaction
- Dealing with synonymy
- **Explosion of complexity!** Before reaching consensus



Average memory per agent
Here, at peak, ~10 words per meaning

Number of different words for same meaning

Reaching consensus, % of successful interactions

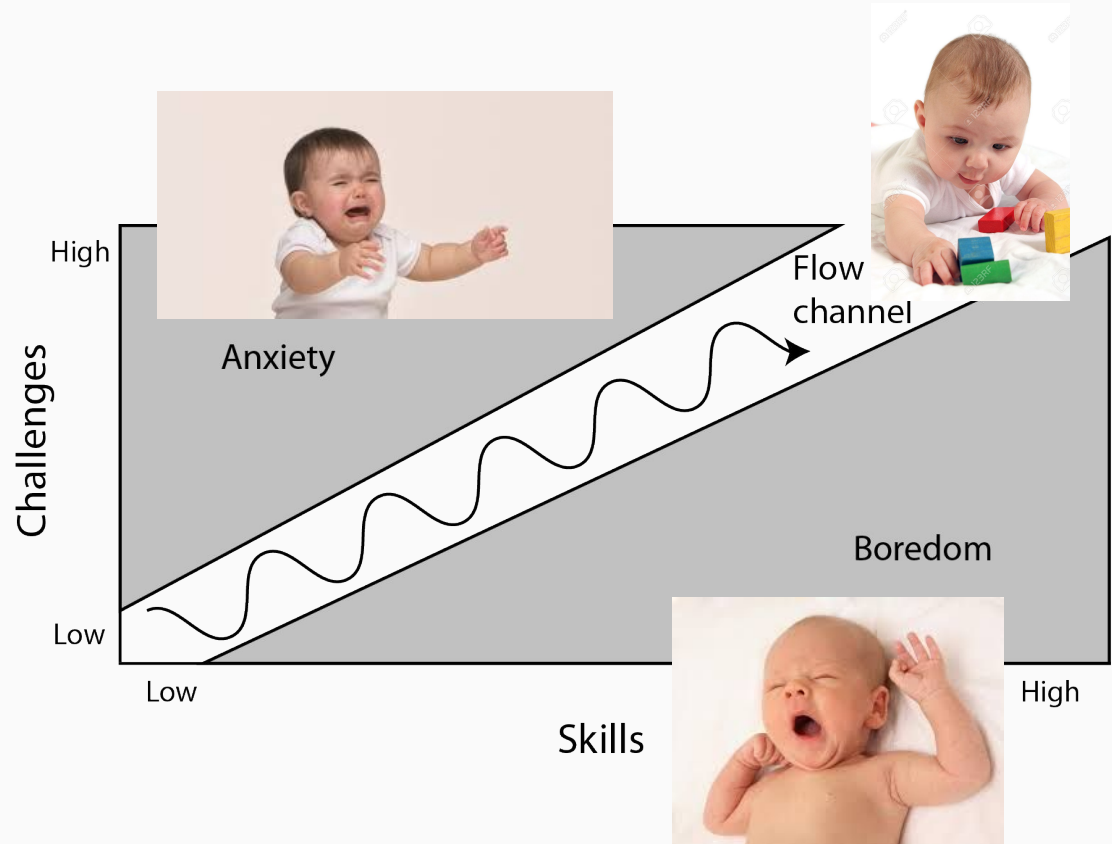
Control of complexity?

Young children are really efficient learners, how do they do? How do they influence their learning process?

Control of complexity?

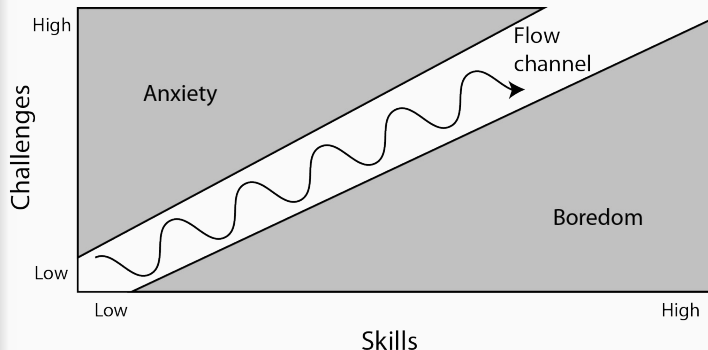
- **Flow theory:** choose challenges neither too complex, neither too simple.
- Intrinsic motivation, curiosity: controlling complexity growth
- Developmental paths (learn to move arms before walking, helps to keep balance; babble before talking, etc)

Young children are really efficient learners, how do they do? How do they influence their learning process?



Control of complexity?

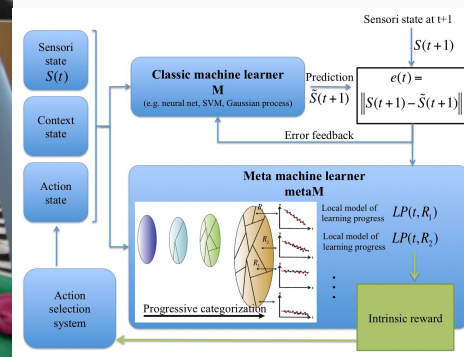
- **Flow theory:** choose challenges neither too complex, neither too simple.
- Intrinsic motivation, curiosity: controlling complexity growth
- Developmental paths (learn to move arms before walking, helps to keep balance)
- **Learning progress maximization**
- Motor skills learning, language learning (babbling, syllables, simple words, sentences), ...
- What about “common social learning”? (Agreeing on new conventions)



Pierre-Yves Oudeyer



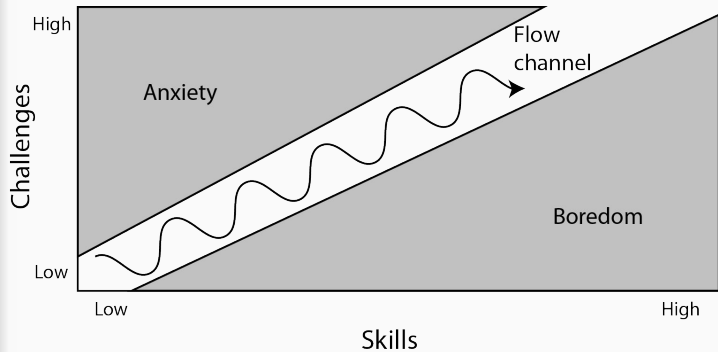
Robots learning basic motor and language skills : like children?



Interest models

Control of complexity?

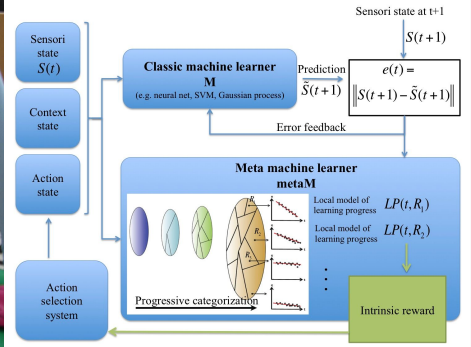
What about “common social learning”? (Agreeing on new conventions)



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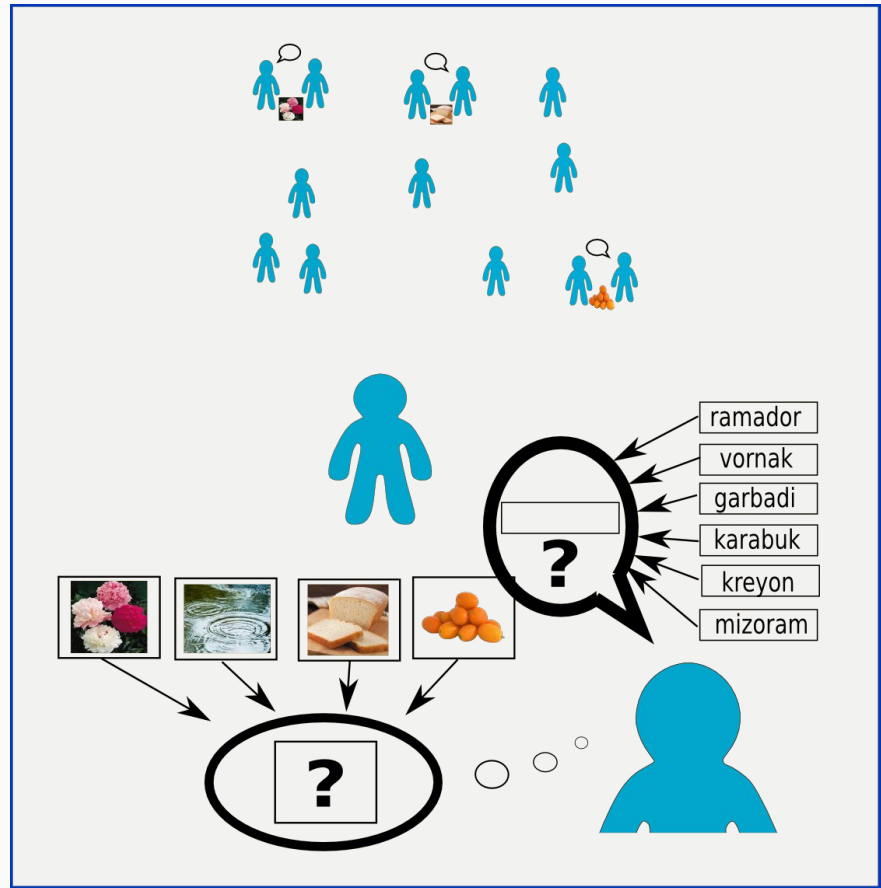
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Interest models

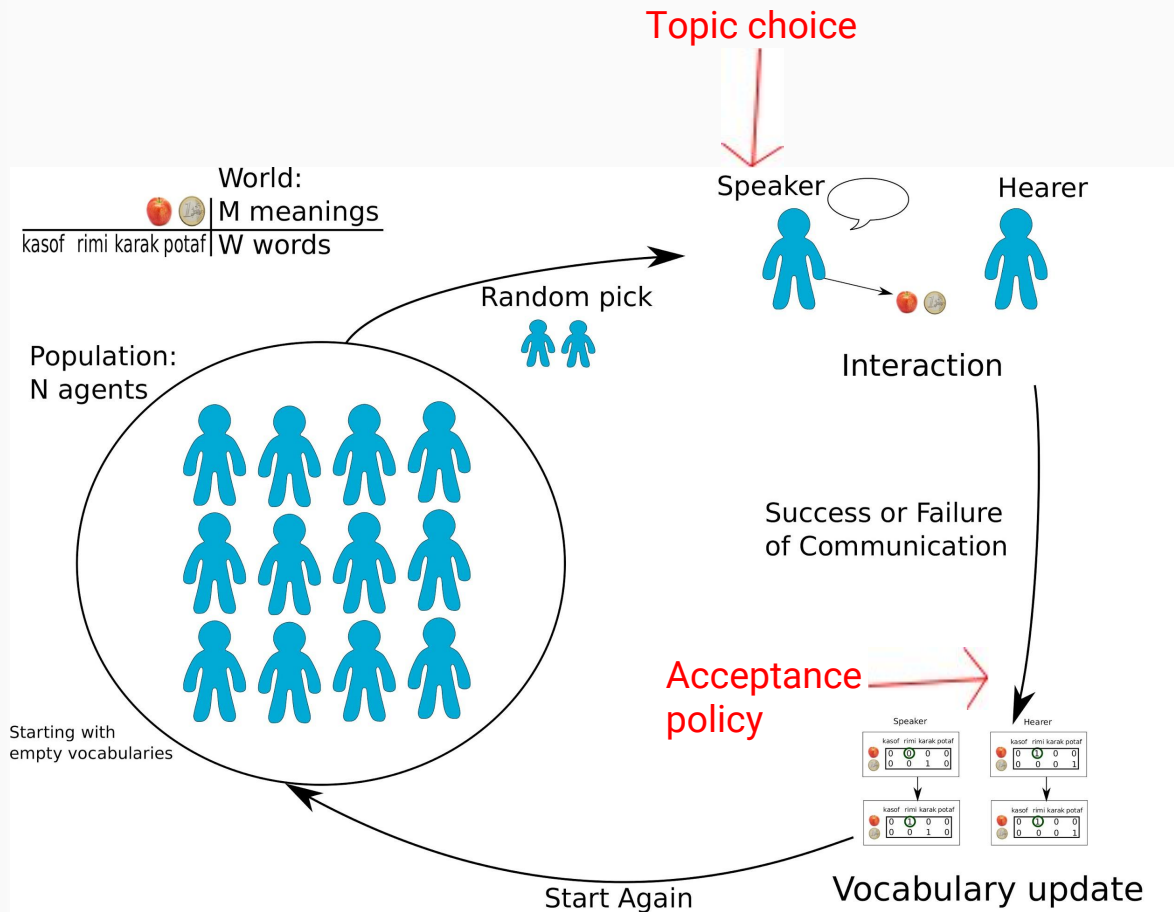
Active control of complexity in the Naming Game?

- Several choices!



Active control of complexity in the Naming Game?


- Several choices!
 - Topic choice (before interaction)
 - Acceptance policy (after interaction): trust or not the other
 - ...



Active Topic Choice

- Stick to few meanings, later only explore others

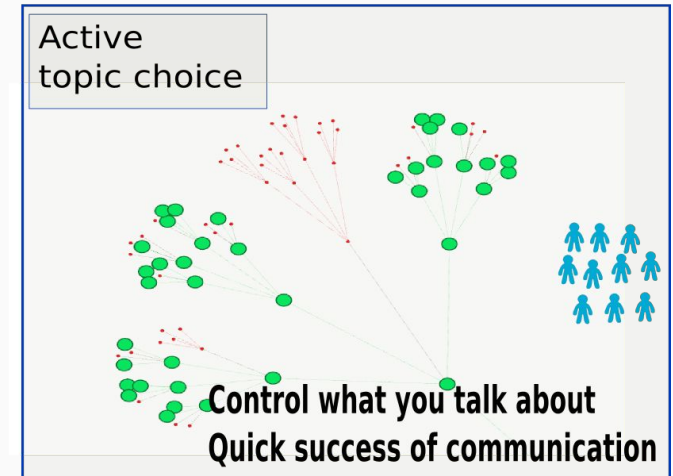
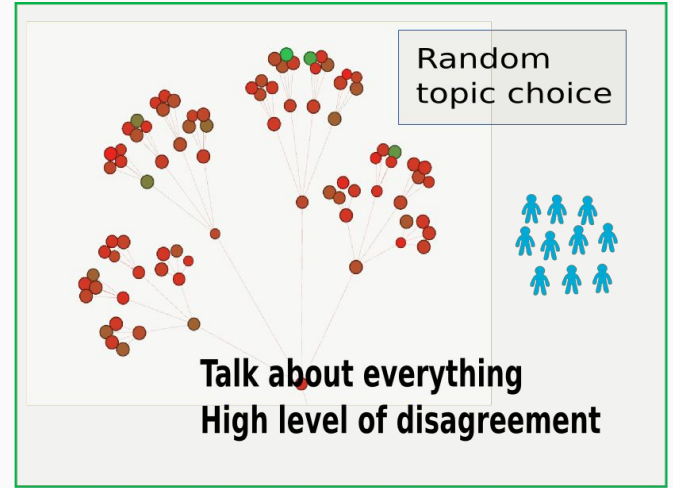
CONTROLLING RATE OF INNOVATION (exploitation/exploration)

○ = 1 meaning, for example: 

Agreement level



Usage in population

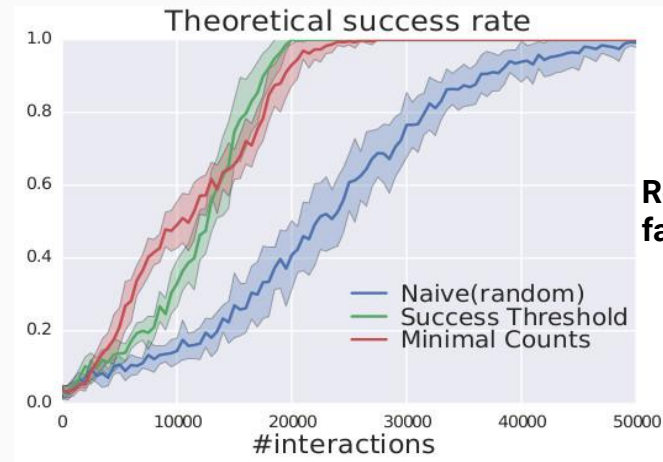


Active Topic Choice

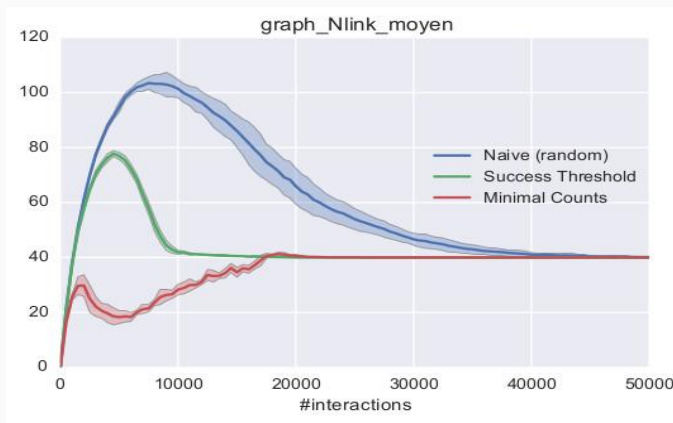
- Stick to few meanings, later only explore others
- Several algorithms based on measures of confidence

Random choice

Active choice



Reach consensus faster



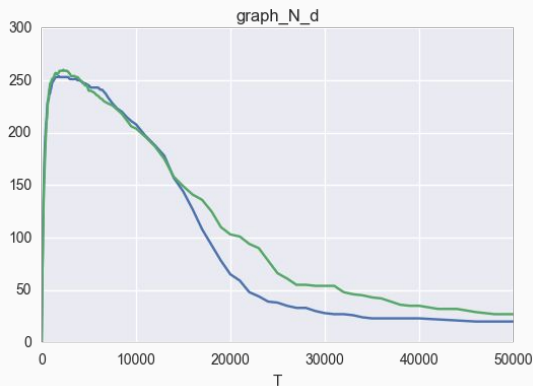
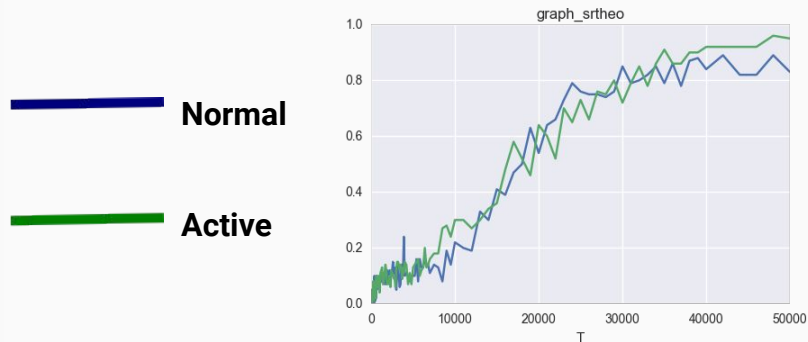
Less memory usage

Active control of complexity growth !

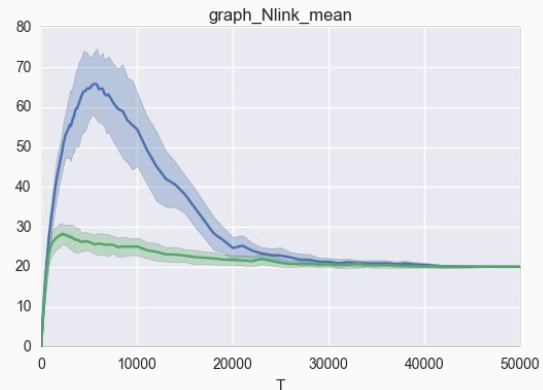
Acceptance policy: “Do I trust what he just said?”

- Stick to few meanings, later only explore others
- Several algorithms based on measures of confidence

Local complexity (memory)
remains low!



Local complexity



Human behavior?

Previous Naming Game
experiments:

Issues:

- Recruiting users
- Getting/keeping them motivated
- If interacting together, should not abandon
- Having relevant measures and results

Human behavior?

Previous Naming Game experiments:

- A. Baronchelli and D. Centola: single meaning, no active topic choice possible, focused on social network properties

MIT | Name Game

Welcome, Damon

Please choose the name that you think best fits the highlighted image below.

Possible: 0 Score: 0 Time left: :20 Total winnings: \$0.00

Players

- Wicked5
- Player5
- Player4
- Player3
- Killer
- DPlayer
- Cder
- SuperP
- D_plays
- Wicked-p
- Dmoney

Kelsie

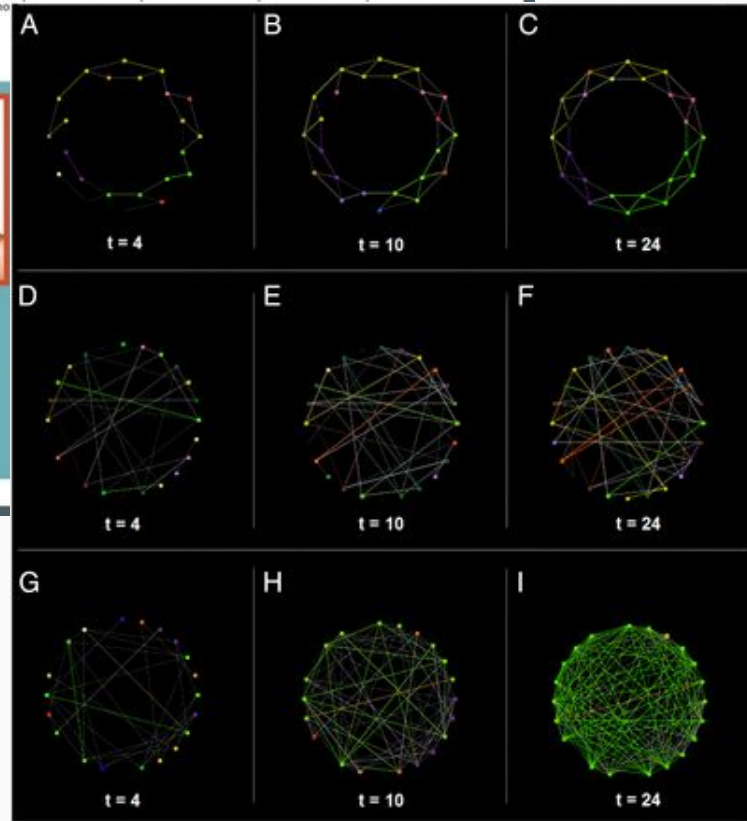
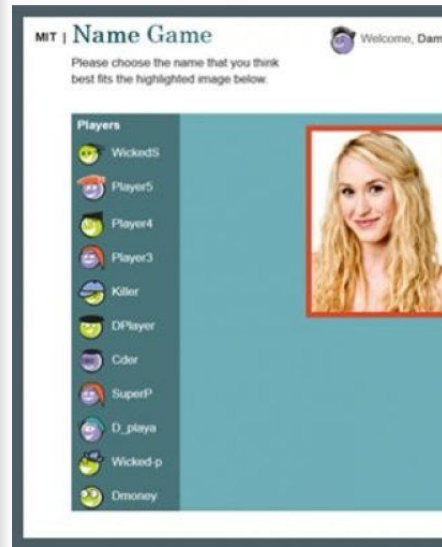
Send choice

Round 1: In play
Round 2:
Round 3:
Round 4:
Round 5:
Round 6:
Round 7:
Round 8:
Round 9:
Round 10:
Round 11:
Round 12:
Round 13:
Round 14:
Round 15:
Round 16:
Round 17:
Round 18:
Round 19:
Round 20:

Human behavior?

Previous Naming Game experiments:

- A. Baronchelli and D. Centola: single meaning, no active topic choice possible, focused on social network properties



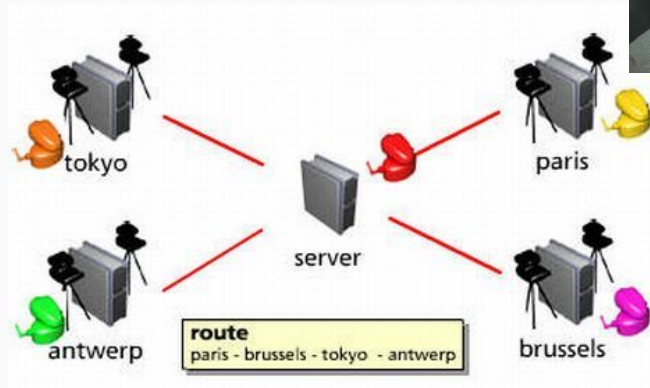
**Network of potential neighbors:
Consensus reached only when everyone
interacts with everyone**

**Important issue:
Gather participants, at the same
time and keep them interested!**

Human behavior?

Previous Naming Game experiments:

- Talking Heads (Luc Steels) : too global, consensus not a goal per se, more about the artificial agents



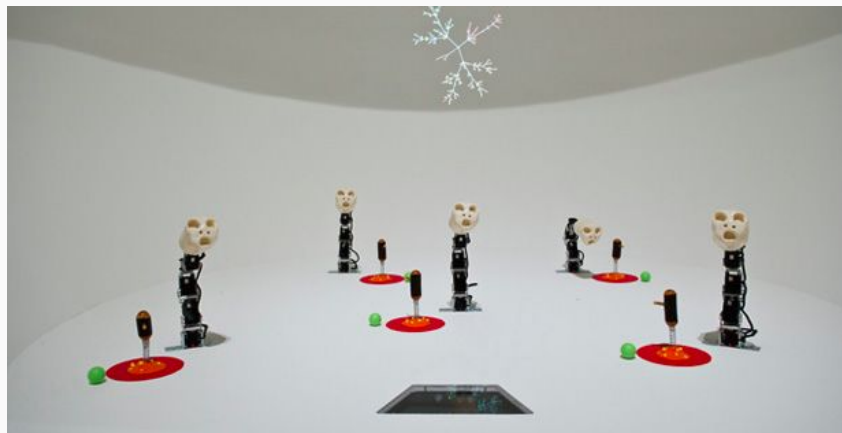
People can interact with the agents and force their own words in the system. But:

1. Actual words already exist (square, red, circle, ...)
2. The experiment focused on the dynamics of the simulated agents' conventions


Human behavior?

Previous Naming Game experiments:

- Ergo-robots: artistic display of the model




L'Expérience Ergo-Robots




Fondation Cartier pour l'art contemporain


« Mathématiques, un Dépassement Soudain »
Fondation Cartier pour l'Art Contemporain, Paris



Mikhail Gromov
Mathématicien
(prix Abel 2009)



David Lynch
Réalisateur, artiste



Pierre-Yves Oudeyer
A good supervisor

<http://flowers.inria.fr/ergo-robots.php>

Free participants, but data is not relevant!

New experiment platform : an actual game !

- Focused on meaning choice and meaning exploration
- For the moment only one user at a time + simulated agents
- Maximizing a score (probability of successful communication at the end)

- Measures:
 - Bias innovation vs. reusing known meanings
 - Rational choice?
 - Persistence of own inventions (IKEA effect?)

italiano

Interaction #26 / 100

Home

Past Interactions

		wawano	✗
		hugane	✗
		hugane	✓
		bumepi	✗
		qenumo	✗
		qenumo	✓
		qenumo	✓

what do you want to talk about?

Using which word?

bumepi faxeme

gugijo hugane

qenumo wawano

Interact

You are the SPEAKER!

<http://kreyon.net/naming-game>

Or just outside, with the other experiments !

New experiment platform : an actual game !

Maybe by tomorrow, bonus types of experiments:

- Successfully communicating about meanings unravels new ones (motivation other than the score)
- Collective experiment, reusing agents who interacted with other people.

The screenshot shows the 'Naming Game' interface in Italian. At the top left is a button labeled 'Italiano' and at the top right is a button labeled 'Home'. The main title is 'Interaction #26 / 100'. Below this, the question 'what do you want to talk about?' is displayed above five image options: flowers, water ripples, bread, oranges, and a hat. Below the images is the question 'Using which word?' followed by six buttons with the words: bumepi, faxeme, gugijo, hugane, qenumo, and wawano. At the bottom center is a blue 'Interact' button. On the left side, a 'Past Interactions' table shows a list of previous interactions with icons, words, and success/failure markers (red X or green checkmark).

Past Interactions		
	wawano	✗
	hugane	✗
	hugane	✓
	bumepi	✗
	qenumo	✗
	qenumo	✓
	qenumo	✓

On the right side, there is a visual representation of the game environment with a group of blue person icons and a green person icon with a speech bubble. Below this, the text reads 'You are the SPEAKER!'.

<http://kreyon.net/naming-game>

Or just outside !

Thanks



Elisabetta
Falivene



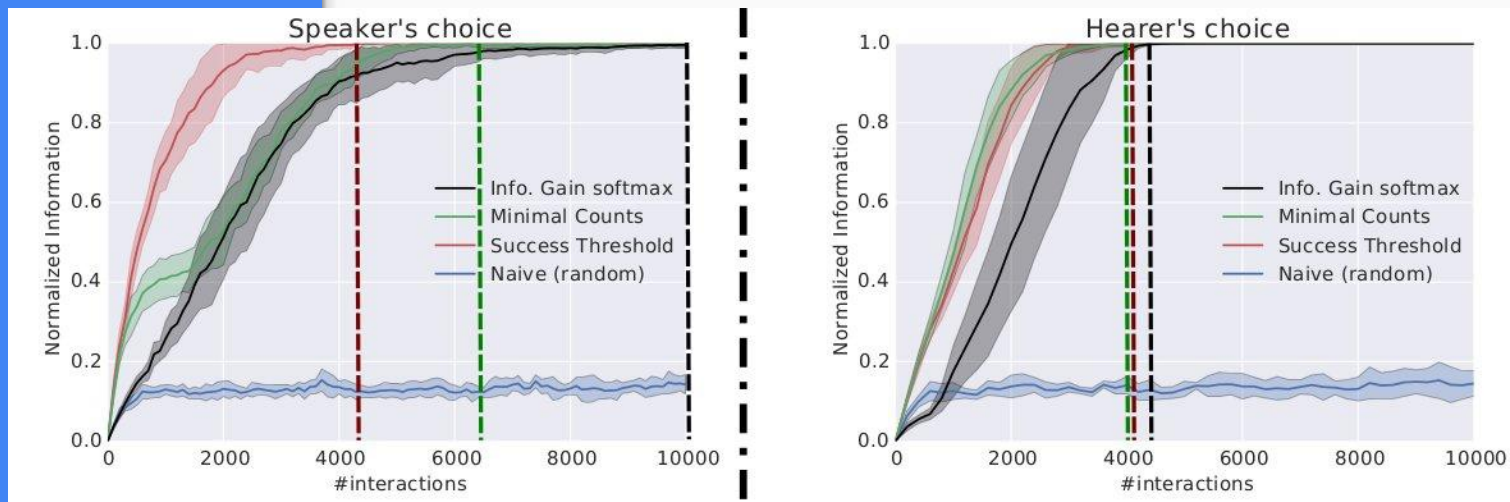
Théo
Segonds

Usual strategies

Success Threshold

Minimal Counts

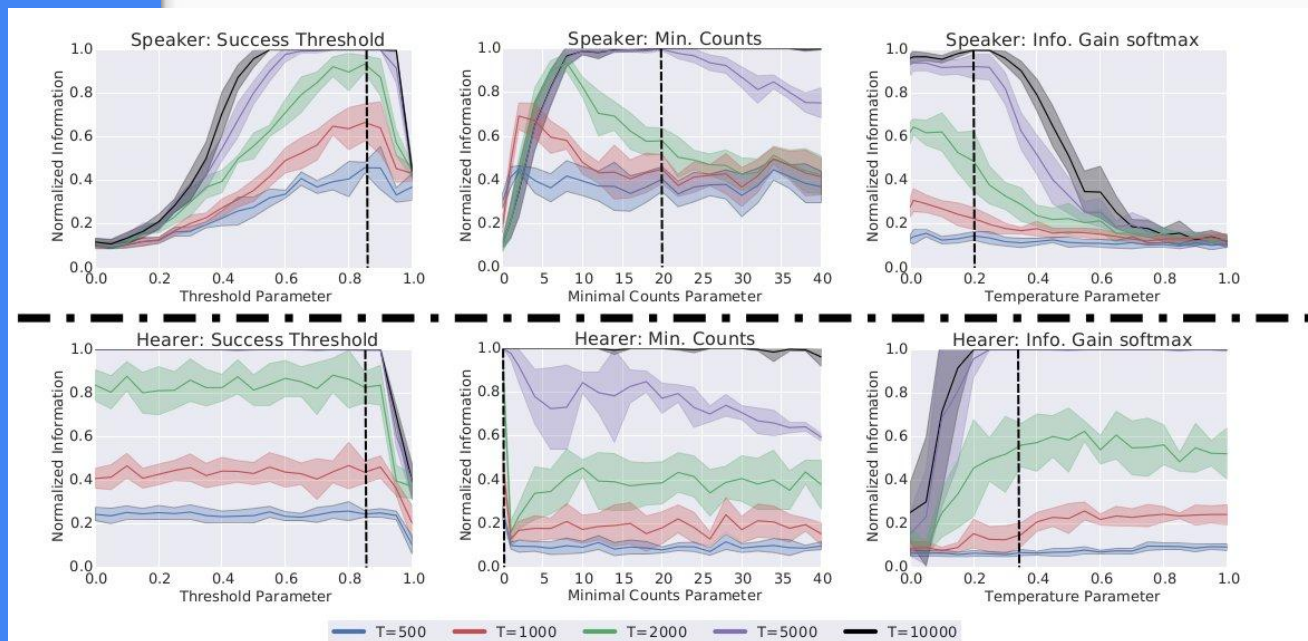
Hearer's choice



- Naive strategy converges slowly (after 1.000.000 interactions – not depicted here).
- **Hearer's choice policy is more efficient** for all active learning strategies.
- Last 5% of information are acquired slower when the speaker is choosing.

Vertical lines show full convergence time for each strategy. ($M=W=N=20$, averaged over 8 trials)

Hearer's choice



Convergence speed dependence on strategy parameters, for active 3 strategies and 2 active interaction scenarios. In all cases **hearer's choice scenario parameters are more robust** to change in value. Snapshots are taken for concurrent strategies spanning a relevant parameter interval, at different time steps (500, 1000, 2000, 5000, 10,000 interactions). Vertical lines show parameter values chosen for the comparisons in results section. ($M=W=N=20$, averaged over 8 trials)

Online platforms

- Amazon Mechanical Turk
- CrowdCurio

Python library

Important features:

- Modularity
- Open source
- Reproducible research
- Scalable on cluster
- Easy to read, modify and evolve (Supposed to be)

```
}
    },
    "success_cfg": {
        "success_type": "global"
    },
    "strat_type": "naive_category_pone"
    },
    "nbagent": 20,
    "voc_cfg": {
        "voc_type": "category"
    }
}
}

In [4]: db = template_obj.get_db(n=name)
db.move_to_RAM()
batch = template_obj.get_batch(n=name,batch_type=batch_type, db=db)

In [5]: cfg_list = []

for interact in interact_l:
    for param in param_l:
        for sensor in sensor_l:
            for N in N_l:
                cfg_list += [(('xp_cfg':template_obj.xp_cfg from dict(n=name,
                                                                    strat=s,
                                                                    param=param,
                                                                    sensor=sensor,
                                                                    interact=interact,
                                                                    N=N),
                                                                    'method':'ntd_l-ntd_global_l',
                                                                    'max_iter':100,
                                                                    'nb_iter':'nb_iter')
                                                                    for s in strategies)

batch_add_jobs(cfg_list)

In [6]: db.get_back_from_RAM()
batch.auto_finish_queue(t=0,coeff=2)
db.move_to_RAM()

[2017 01 31 15:42:26]: Queue updated
total: 0

execution time: 0 s
jobs done: 0

In [7]: %matplotlib inline

for interact in interact_l:
    print interact
    xp_cfg_l = []
    for sensor in sensor_l:
        xp_cfg_l += [template_obj.xp_cfg from dict(n=name,
                                                    strat=s,
                                                    interact=interact,
                                                    sensor=sensor,
                                                    N=nbagent) for s in strategies]

    for mt in ntd_l:
        graph = template_obj.get_graph(ntd=nt, xp_cfg_l=xp_cfg_l, nbniter=nb_iter, p_l=param_l, db=db)
        graph.show()
        graph.semilog = False
        graph.show()
        graph.semilog = True
        graph.show()

('Interact_type': 'category_pone')

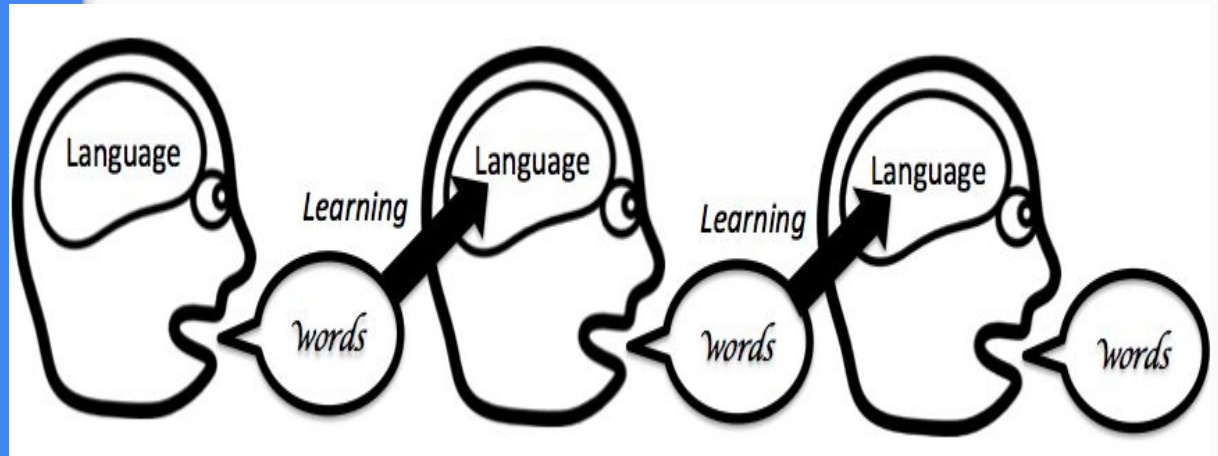
graph_srthao_cat
0.0 0.2 0.4 0.6 0.8 1.0
naive_category_pone (uniform_hue_d_min=0.1)
naive_category_pone (uniform_hue_d_min=0.01)
naive_category_pone (human_hue)
0 2000 4000 6000 8000 10000
#iterations

graph_srthwo_cat
0.6 0.8 1.0
naive_category_pone (uniform_hue_d_min=0.1)
naive_category_pone (uniform_hue_d_min=0.01)
naive_category_pone (human_hue)
```

Human behavior?

Previous Naming Game experiments:

- Iterated Learning (K. Smith and S. Kirby):
every user is a “generation”,
no need to sync users

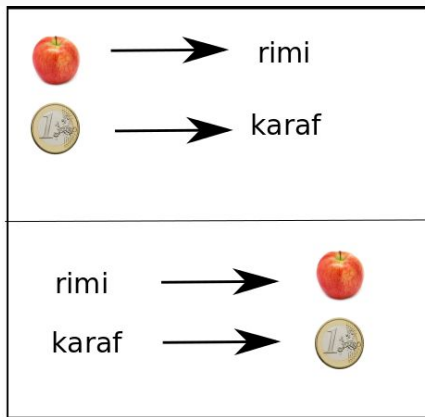


Definition of the local measure of probability of success





What is used by the agent?

- Vocabulary
- Memory of past interactions

Idea: build an approximation of the 'average vocabulary' in the population using this memory, and compute probability of success



Vocabulary

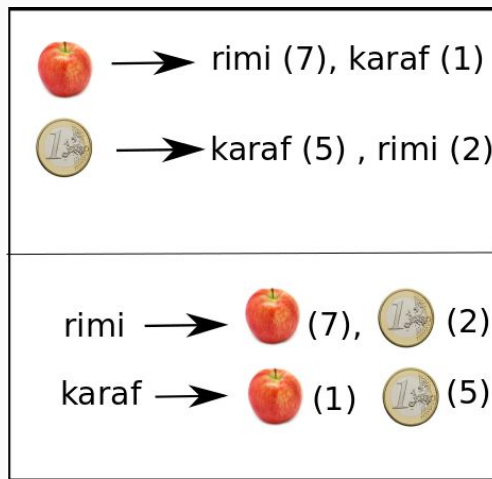
	rimi	7
	karaf	5
	karaf	1
	rimi	2

#Past interactions





Definition of the local measure of probability of success

Normalization: only retain maximum t interaction per meaning or word

(ignore past interactions older than t -> sliding window per meaning and per word)



Vocabulary approximation

	rimi	7
	karaf	5
	karaf	1
	rimi	2







#Past interactions





Definition of the local measure of probability of success

Normalization: only retain maximum $t = 10$ interactions per meaning or word

(ignore past interactions older than $t \rightarrow$ sliding window per meaning and per word)

Consider 2 possible options: success when speaker, success when hearer, then average over meanings

	\rightarrow	rimi (7/10), karaf (1/10)
	\rightarrow	karaf (5/10), rimi (2/10)
<hr/>		
rimi	\rightarrow	 (7/10),  (2/10)
karaf	\rightarrow	 (1/10)  (5/10)

	rimi	7
	karaf	5
	karaf	1
	rimi	2

#Past interactions

Vocabulary approximation

$$\begin{aligned}
 SR(\text{apple}, \text{speaker}) &= \left(\text{apple} \rightarrow \text{rimi} \right)_{\text{Voc}} \times \left(\text{rimi} \rightarrow \text{apple} \right)_{\text{Mem}} + \left(\text{apple} \rightarrow \text{karaf} \right)_{\text{Voc}} \times \left(\text{karaf} \rightarrow \text{apple} \right)_{\text{Mem}} \\
 &= 1 \times 7/10 + 0 \times 1/10 \\
 &= 7/10
 \end{aligned}$$

$$\begin{aligned}
 SR(\text{apple}) &= 1/2 * SR(\text{apple}, \text{speaker}) + 1/2 * SR(\text{apple}, \text{hearer}) \\
 &= 0.49
 \end{aligned}$$

$$\begin{aligned}
 SR_{\text{total}} &= 1/M * SR(\text{apple}) + 1/M * SR(\text{coin}) \\
 &= 0.37
 \end{aligned}$$

Definition of the local measure of probability of success

Importance of time scale:

- If too small, too much confidence over new conventions (can be own), and forgetting lots of info
- If too high, evaluation of probability of success can be too small

But always, when over the time period all interactions agree with voc, $SR = 1$

Example with the previous example:

$t = 9 \rightarrow SR = 0.457$

$t = 11 \rightarrow SR = 0.306$

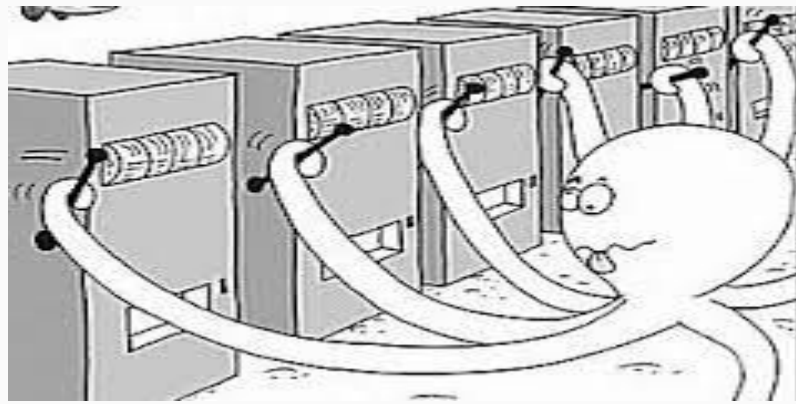
$t = 100 \rightarrow SR = 0.0037$

$t < 9$: impossible because $7+2=9$, would have had to remove oldest interactions from memory

Here, numbers do not sum to 10, some information is still missing from the agent's point of view!

Multi-Armed Bandit

- Algorithms for exploit/explore
- Updating beliefs about reward, not using actual computation of the reward (very costly in our case)



Implemented:

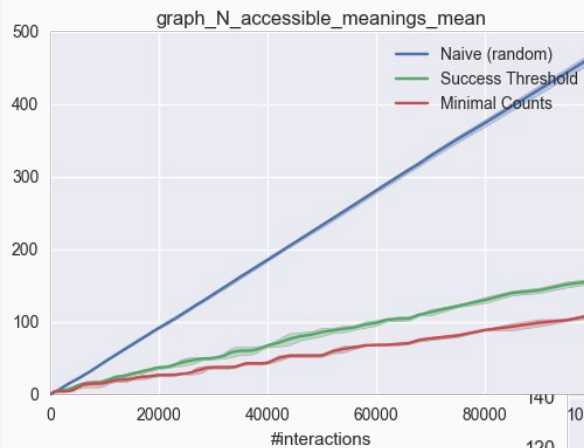
Thompson Sampling, one “slot machine” per meaning + 1 for exploration. New machine (=newly explored meaning) takes current state of exploration machine

Abstract: Collective exploration through communication

Naming Game on a balanced tree (4 children per node), opening up adjacent possible only if condition of 'good communication', for example:

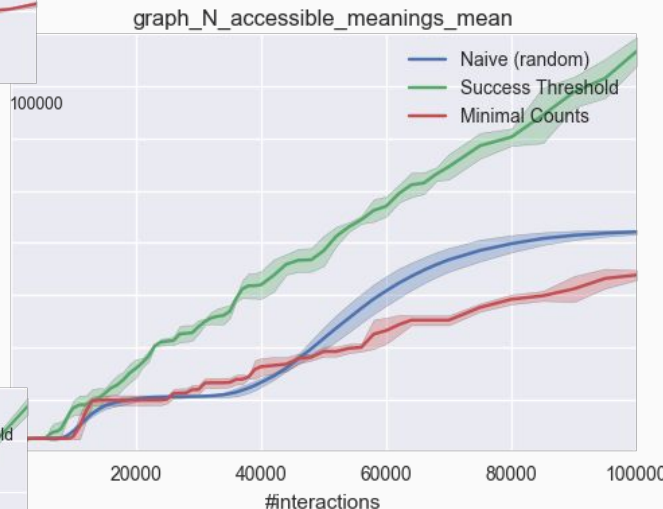
- At least 1 success
- At least k success
- Being certain about this meaning (estimated proba of success = 1)

$N=100, M=W=10^4$



1 success

10 success



Proba of success (m) = 1

