Simulating Language
Lecture 2: Modelling signalling systems

Kenny Smith

kenny.smith@ed.ac.uk

Follow-up from yesterday's labs

- I was impressed!
- Reminder
    - Go to the labs, do the exercises - you can't do programming without doing some programming.
    - Beginners: don't worry, you'll get there. Experienced programmers: don't worry, we'll be using simple code to look at interesting phenomena (communication, evolution, learning, culture, ...)

Starting simple: signalling

- We want a simple starting point for our effort to model the evolution of language

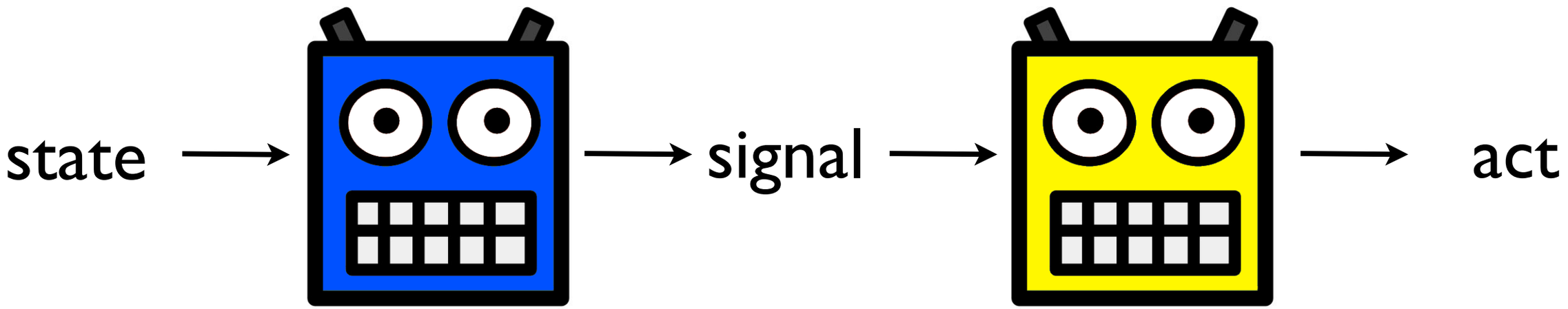
- Look not at language, but communication more broadly. Particularly, the kind of communication we see in many species: (**innate**) signalling

- Example: vervet monkey alarm calls http://www.youtube.com/embed/3lsF83rHKFc

- Calls (and appropriate responses) for: Leopard, eagle, snake

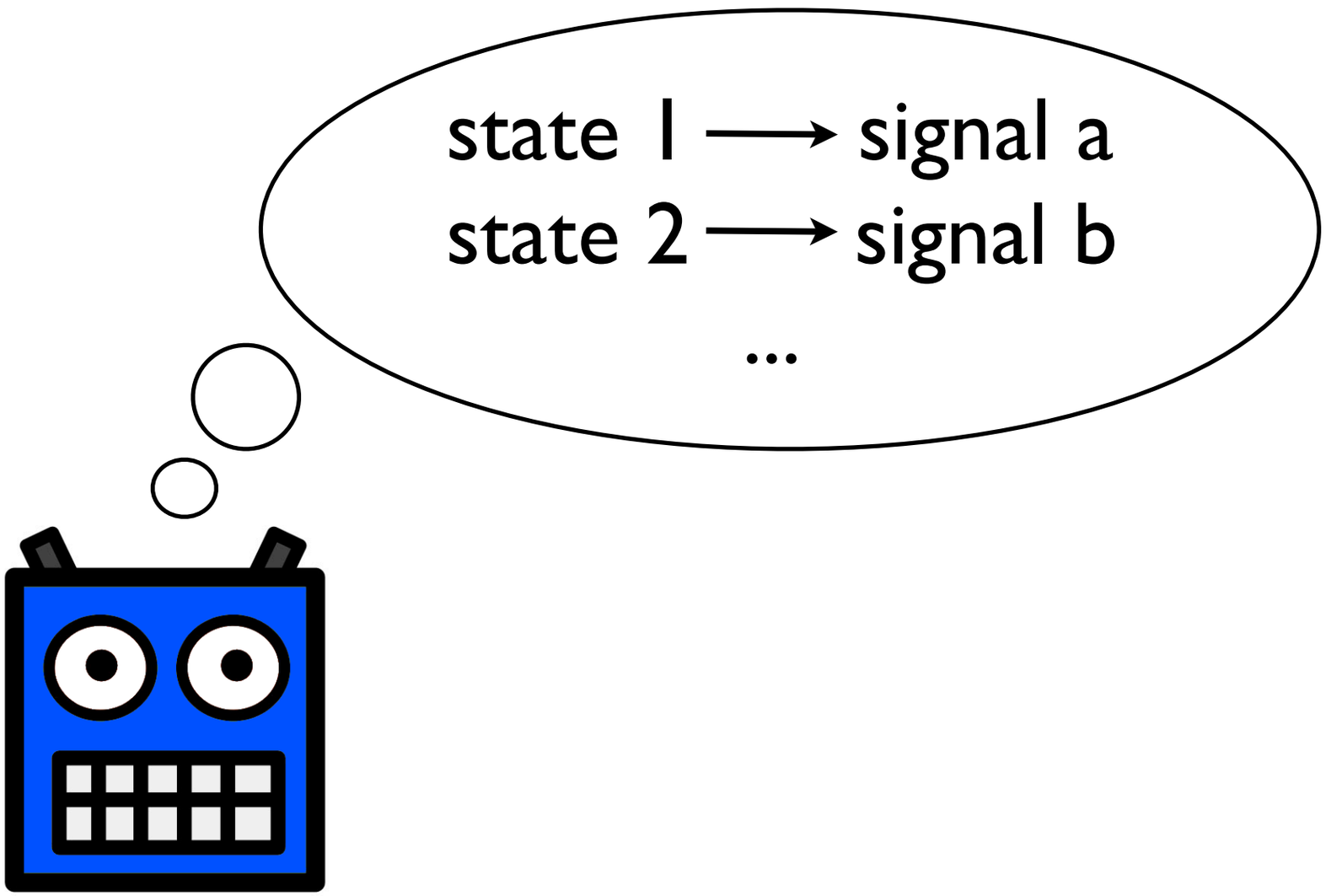
Sender-receiver games

World **Sender** **Receiver** **Acts**



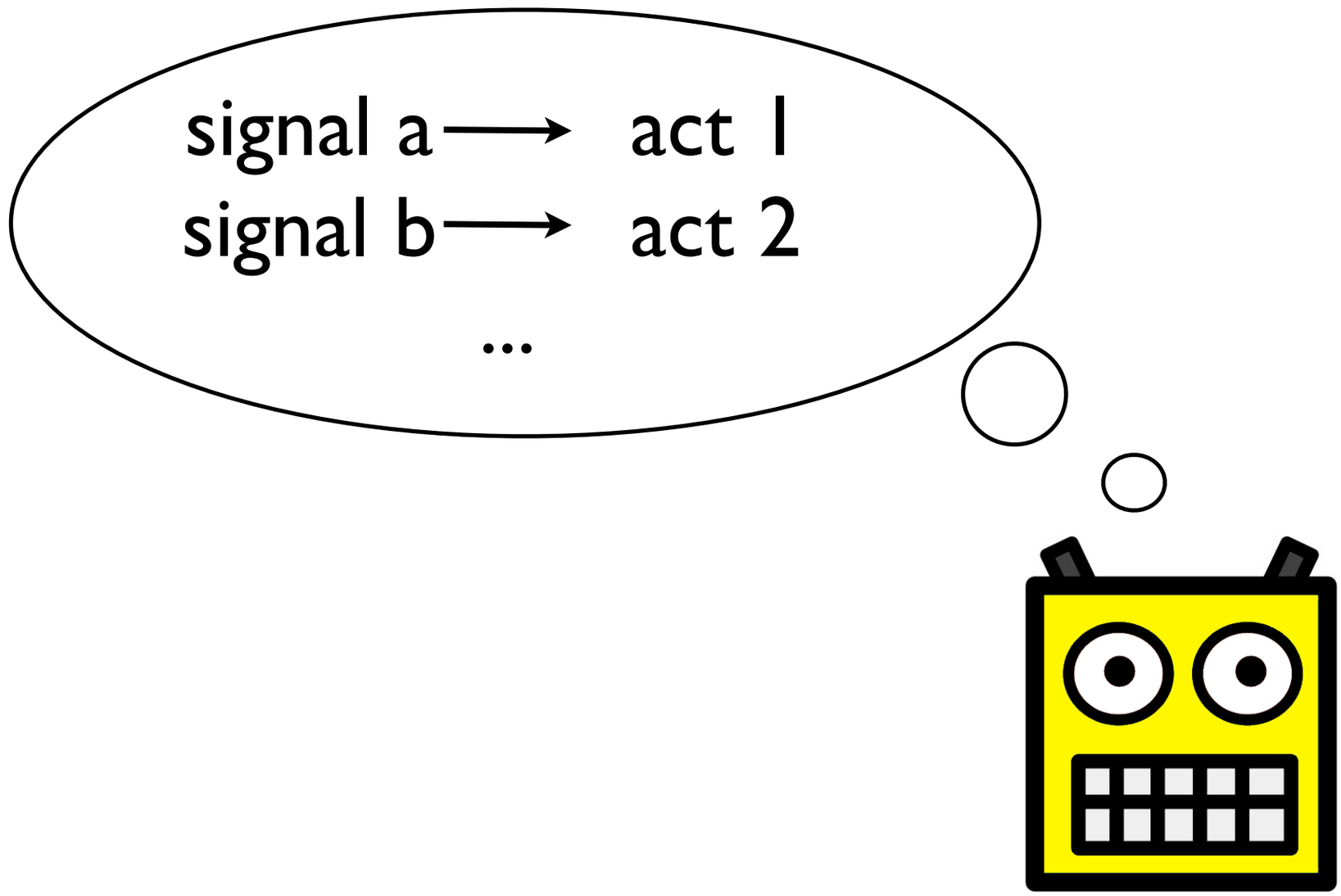
Sender strategy

- Specifies, for every state, the signal to send

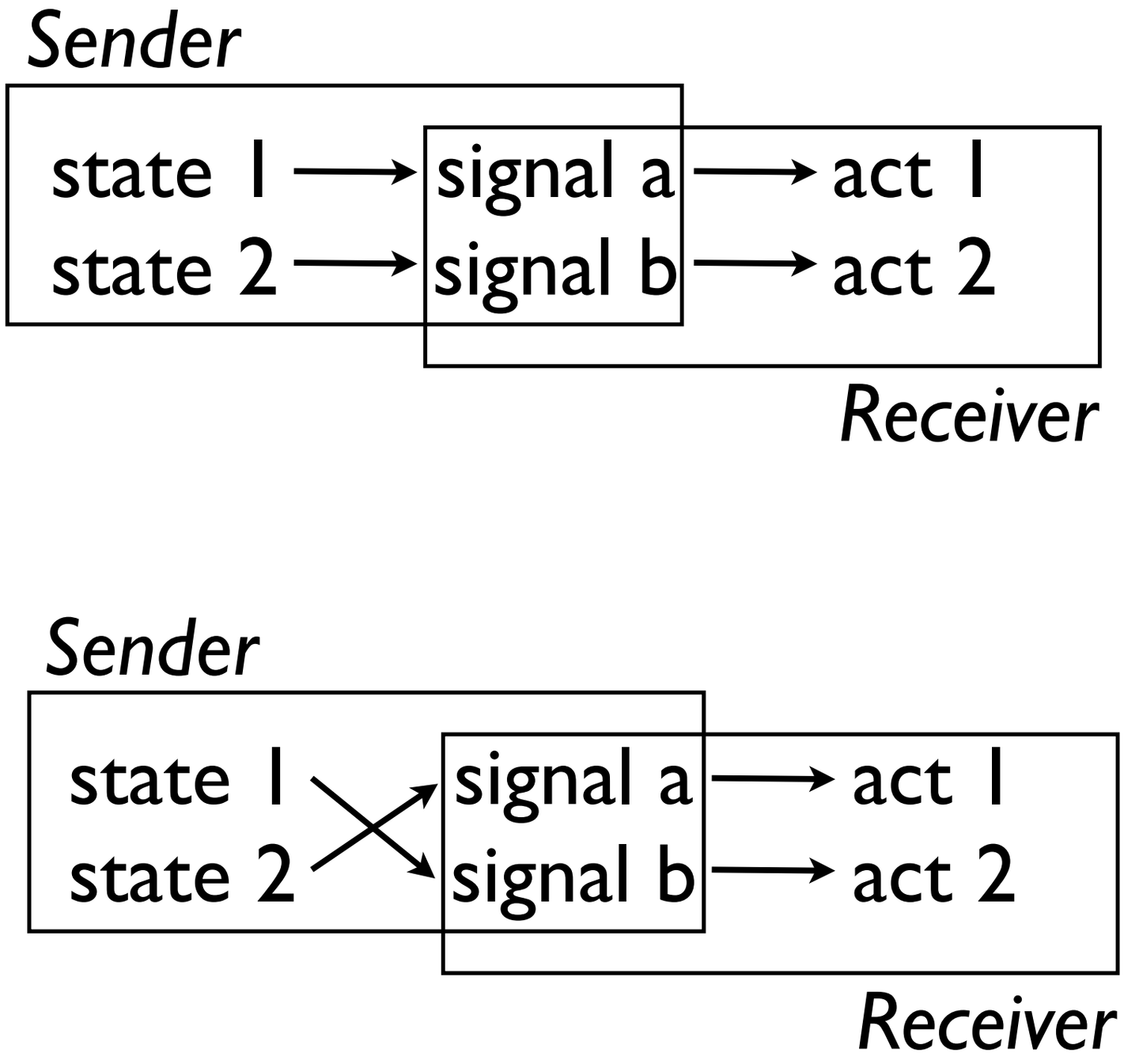


Receiver strategy

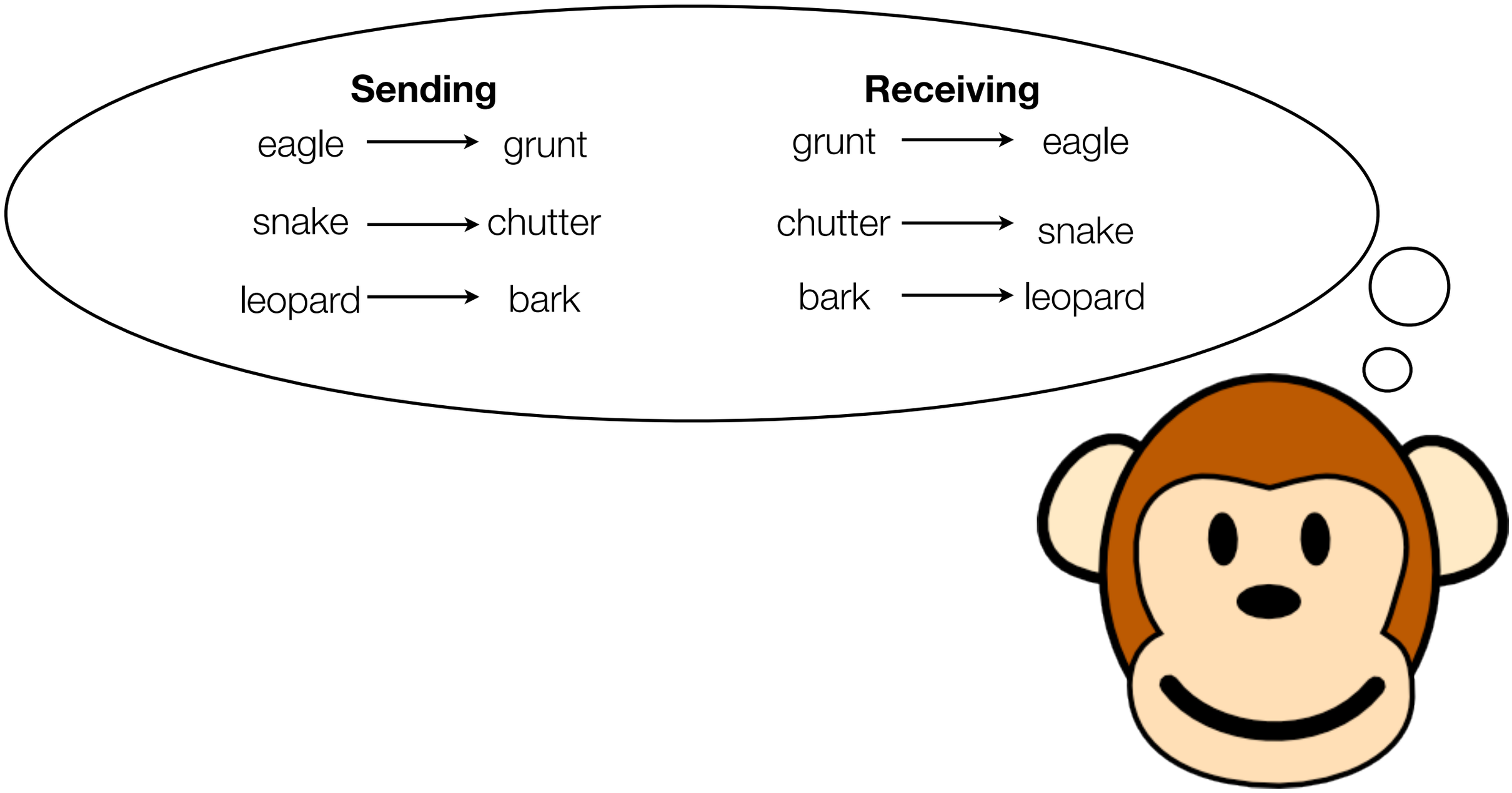
- Specifies, for every signal, the act to perform



Communication



The vervet system



What's **missing** from this as a model of language?

- You said ...

Two questions about the evolution of communication

- How are communicative **conventions** established?

- What ensures those conventions are **communicatively useful**?

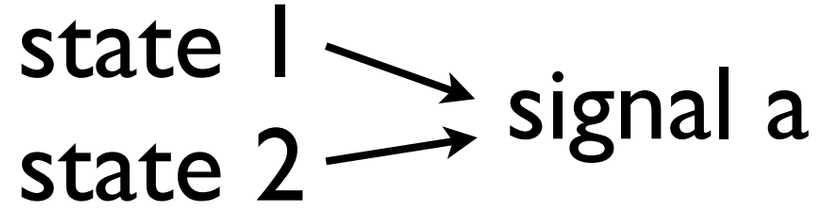
Convention and communication

- Rough definition**:** A convention is a system of behaviour that is **shared** among members of a population

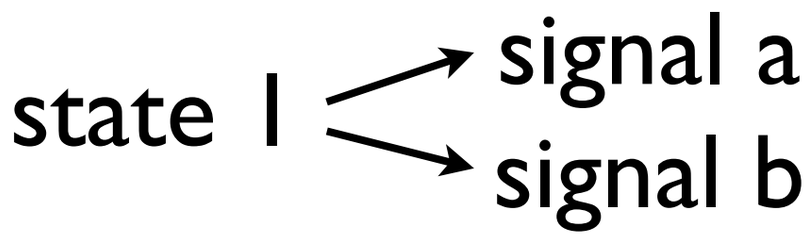
- Two (related) ways in which communication requires convention:
  - Agreement between sender and receiver about what each signal ‘means’
  - Agreement across a population about how to send and how to receive

Communication, homonymy, synonymy

- **Homonymy**: multiple states map to a single signal



- **Synonymy**: a state maps to multiple signals



- **What determines the communicative functionality of a signalling system (in additional to conventionality)?**
  A: homonymy (more is bad)
  B: homonymy (more is good)
  C: synonymy (more is bad)
  D: synonymy (more is good)
  E: both synonymy and homonymy (more is bad)
  F: both synonymy and homonymy (more is good)

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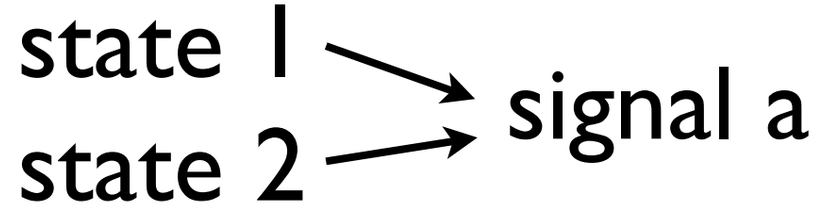
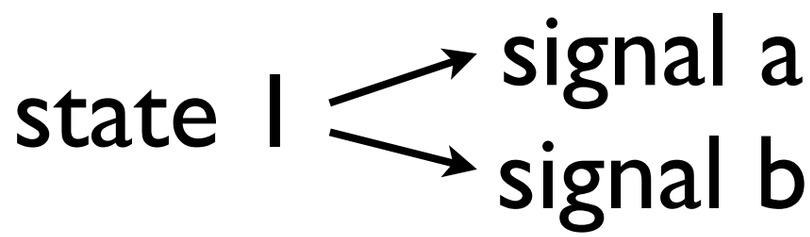
Communication, homonymy, synonymy

- **Homonymy**: multiple states map to a single signal



- **Synonymy**: a state maps to multiple signals



- **What does the lexicon of natural languages look like?**
  A: homonymy and synonymy are rare
  B: homonymy is rare, synonymy is common
  C: homonymy is common, synonymy is rare
  D: homonymy and synonymy are common

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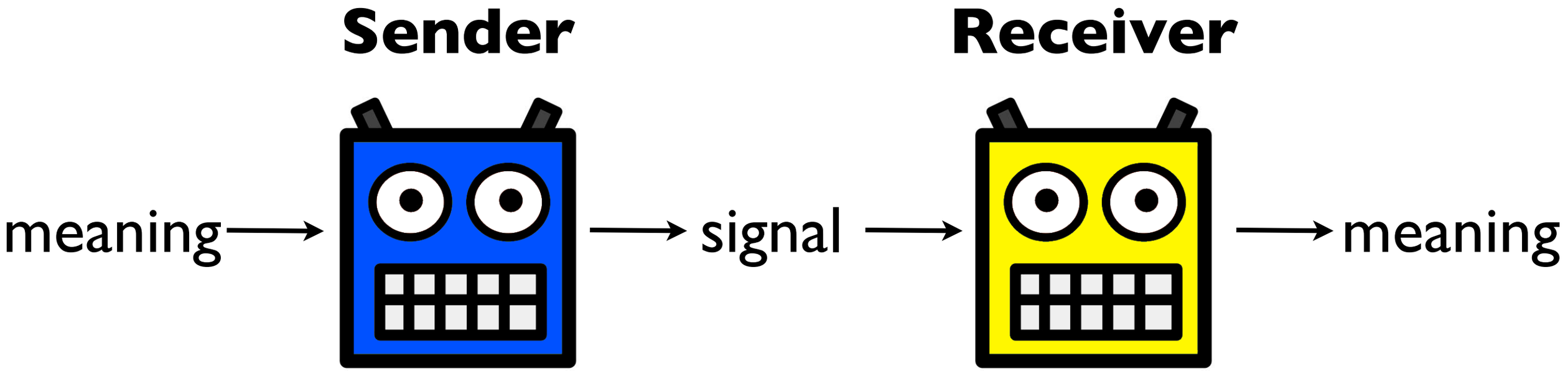
A simplification

- Forget about the distinction between states and acts - *meanings* and *signals*



How to model an agent

- Need to represent the mapping between meanings and signals somehow

- Store *matrices* of associations

Producing

	s1	s2	s3
m1			
m2			
m3			

Receiving

	m1	m2	m3
s1			
s2			
s3			

Use the matrix for production and reception

- How do we take a matrix like this and get it to produce signals?

- One way: *winner take all*

- Production: Look along row for meaning and pick signal with highest association strength

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

Use the matrix for production and reception

- How do we take a matrix like this and get it to receive signals?

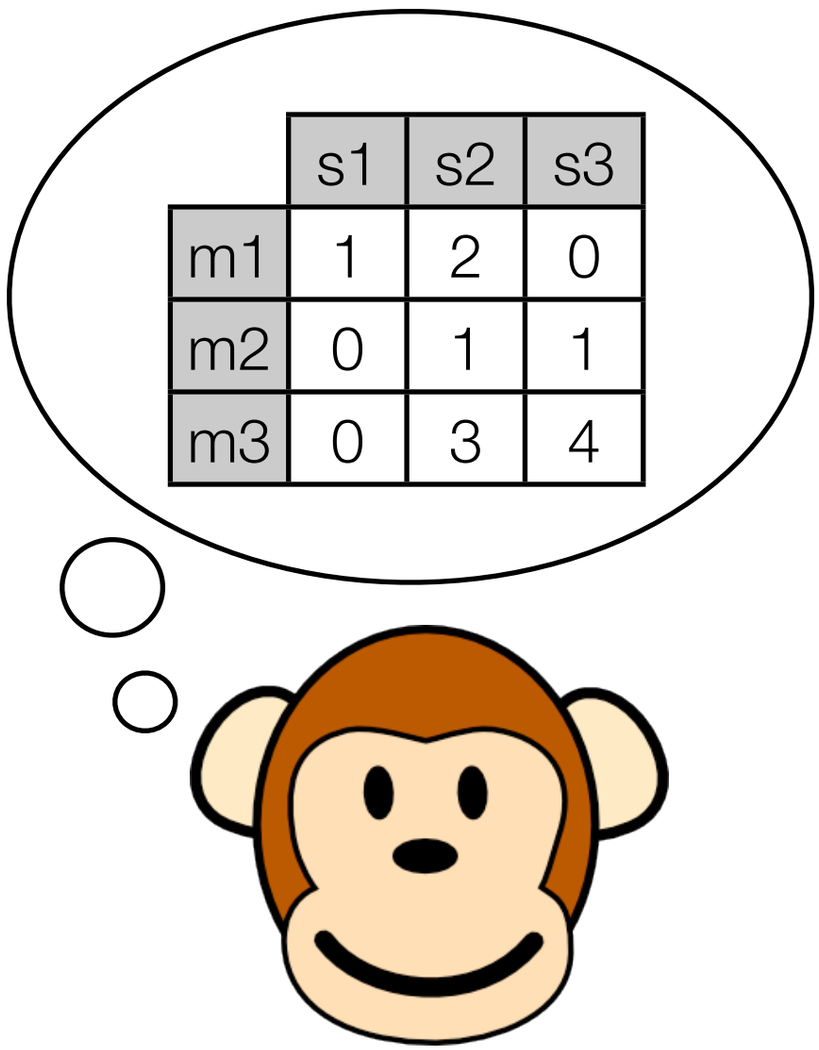
- One way: *winner take all*

- Reception: Look along row for signal and pick meaning with highest association strength

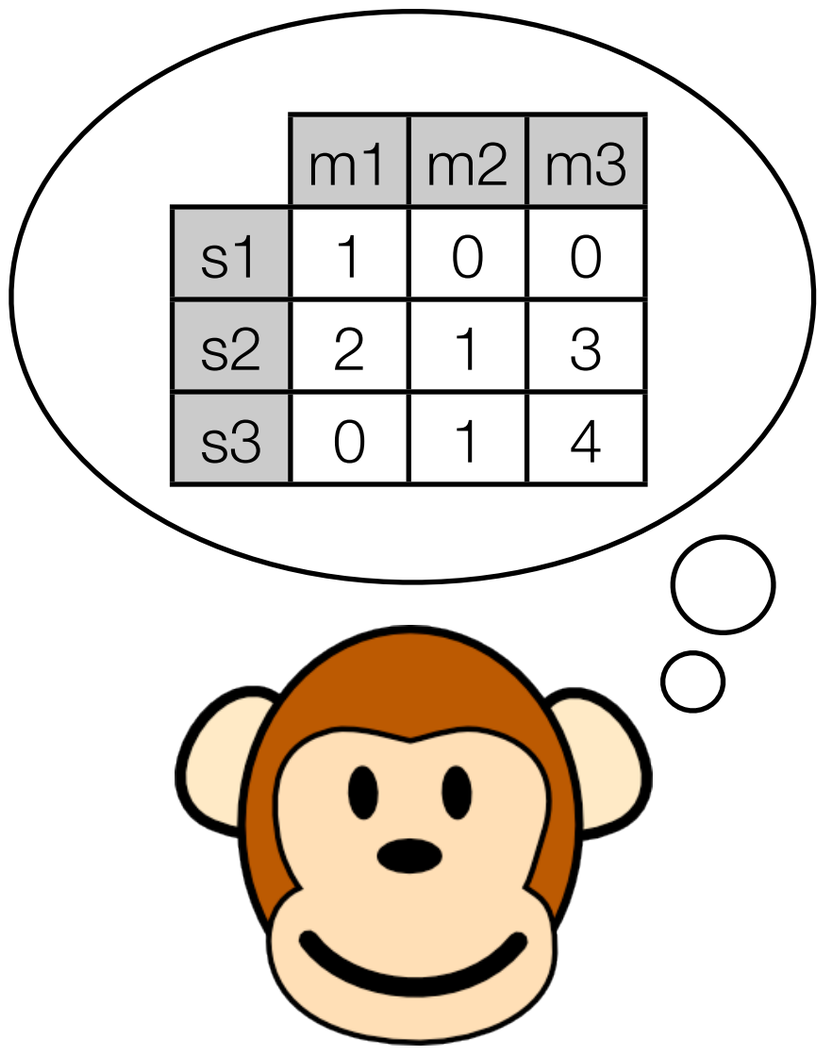
	m1	m2	m3
s1	1	0	0
s2	2	1	3
s3	0	1	4

How can we measure communication success?

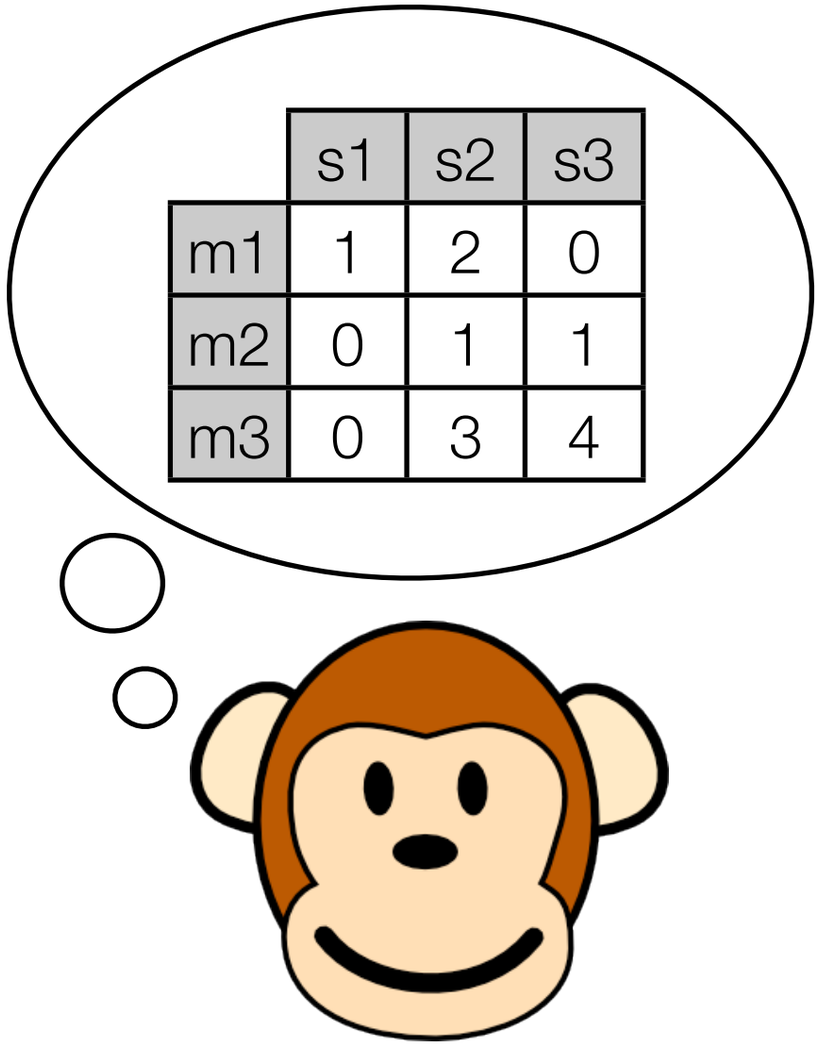
- Now we have a model of signalling, how do we measure how good a signalling system is for communication?



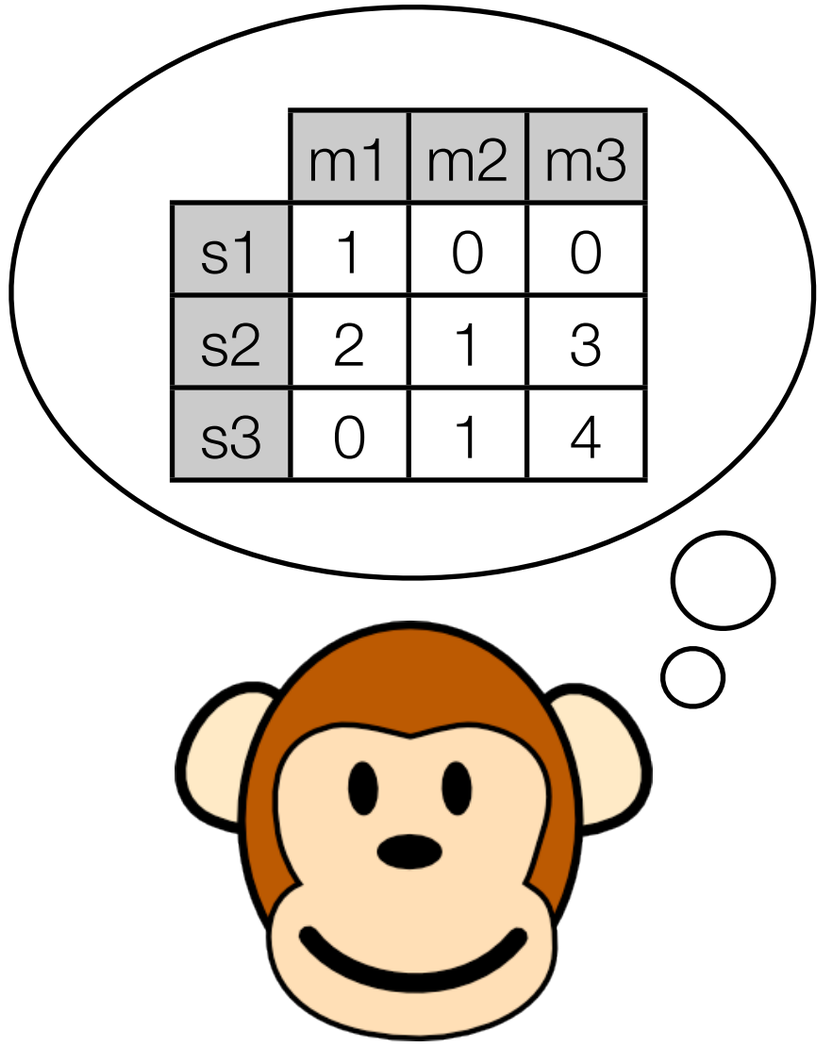
Producer



Receiver



Producer



Receiver

On average, how often will they communicate successfully?

A: Never

B: One third of the time

C: Two thirds of the time

D: Always

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Another way of evaluating communicative accuracy: Monte Carlo simulation

- One way: build a simulation of thousands of communication events between two agents, a producer and a receiver.

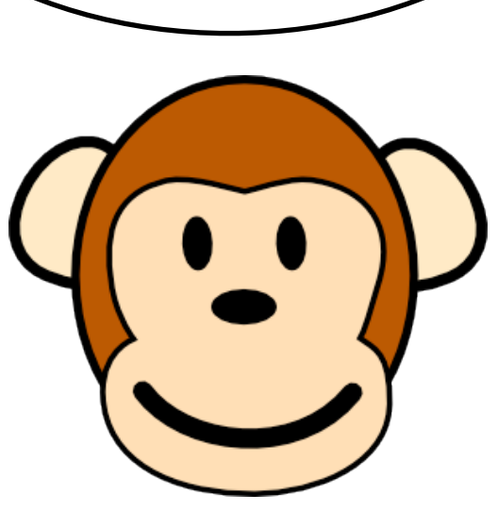
- For a particular producer and receiver, do the following:

1. Pick a random meaning
2. Use winner take all to generate a signal for that meaning according to the producer's production matrix
3. Use winner take all again to see what meaning corresponds to that signal in the receiver's reception matrix
4. If the receiver's meaning is the same as the original one, count as success

- Repeat 1-4 thousands of times and return the proportion of these "trials"

Communicative accuracy

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4



Producer

	m1	m2	m3
s1	1	0	0
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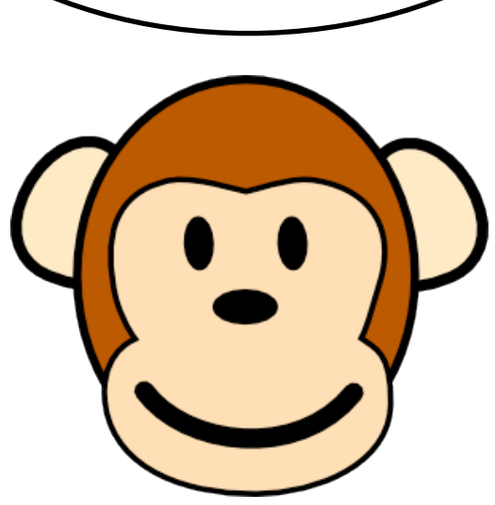

Receiver

Communicative accuracy: 0.33

One way to model matrices in Python

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

```
  my_matrix =
[ [ 1, 2, 0 ],
  [ 0, 1, 1],
  [ 0, 3, 4] ]
```

- **How would you access the row of association strengths for m1?**

  A: Hmm. I don’t know.

  B: my_matrix[0]

  C: my_matrix[1]

One way to model matrices in Python

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

```
my_matrix =
[ [ 1, 2, 0 ],
  [ 0, 1, 1],
  [ 0, 3, 4] ]
```

- **How would you access the strength of association between m2 and s1?**

  A: Hmm. I don’t know.

  B: my_matrix[0][1]

  C: my_matrix[1][0]

One way to model matrices in Python

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

```
my_matrix =
[ [ 1, 2, 0 ],
  [ 0, 1, 1],
  [ 0, 3, 4] ]
```

- **Can you tell, by looking at the python code, that this is a production matrix rather than a reception matrix?**

  A: No

  B: Yes

Some questions for you

- Some signalling systems are better than others. How do animals end up with the best ones?

- What about signalling between two agents with *different* matrices of associations? Will there be different scores for sending versus receiving?

- What about a population of agents, each with different signal systems?

Next

- Monday: **lab** on modelling signalling and communication
- Thursday: first of our *optional* catch-up labs for anyone who is feeling overwhelmed
- Friday: lecture on evolving signalling systems - remember the pre-reading!