The Language Organism
Lecture 2: Modelling signalling systems

Simon Kirby

simon@ling.ed.ac.uk

Starting simple: signalling

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

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

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

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

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

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

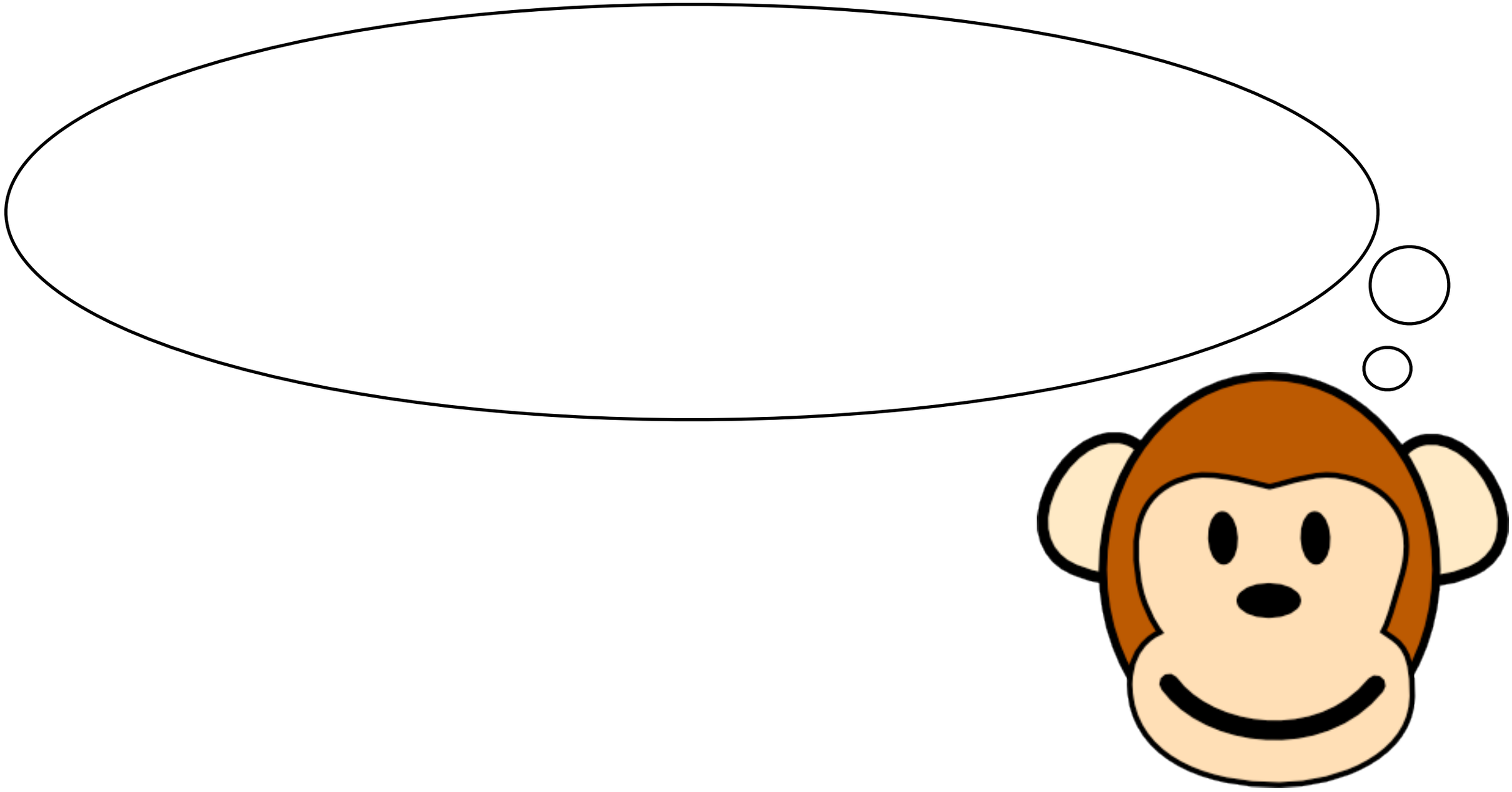
(Very) simple model of signalling

(Very) simple model of signalling

- Mapping between *meanings* and *signals*

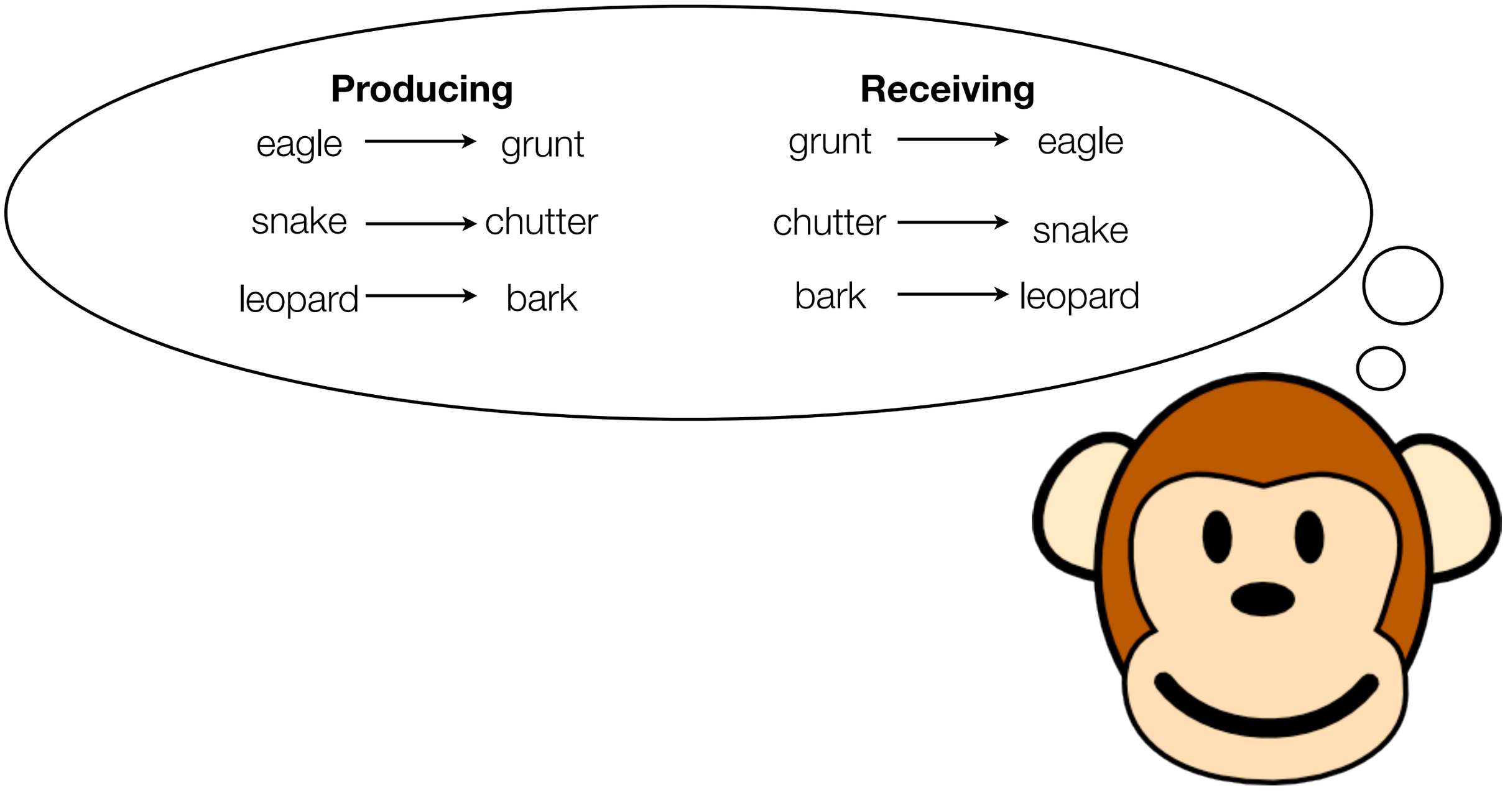
(Very) simple model of signalling

- Mapping between *meanings* and *signals*



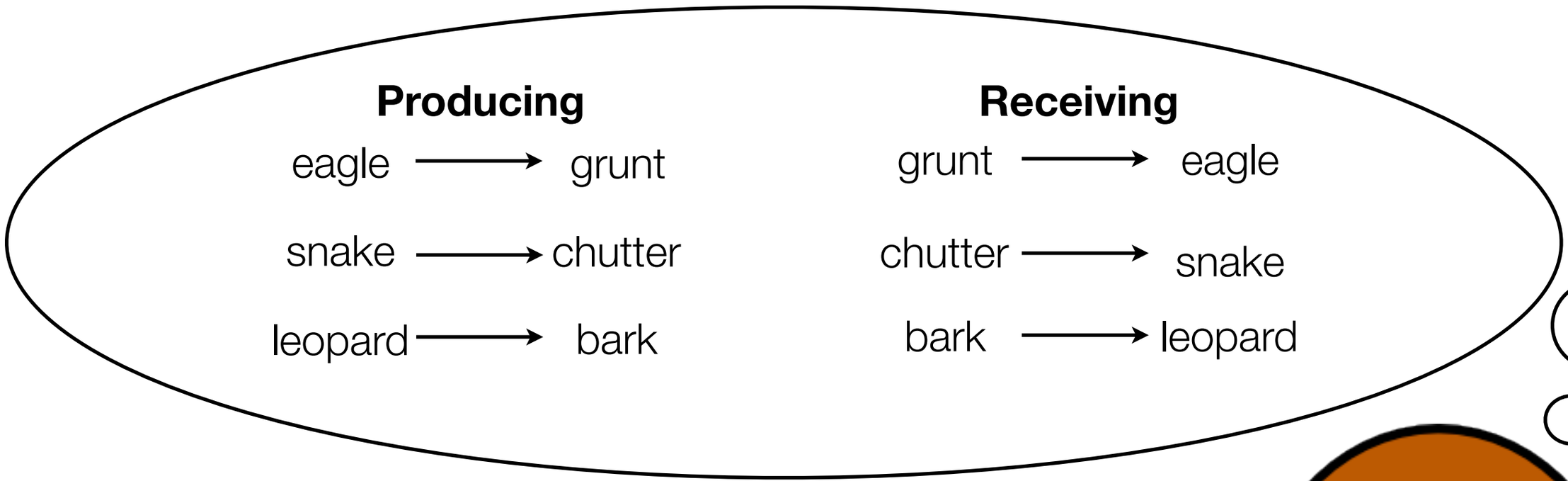
(Very) simple model of signalling

- Mapping between *meanings* and *signals*

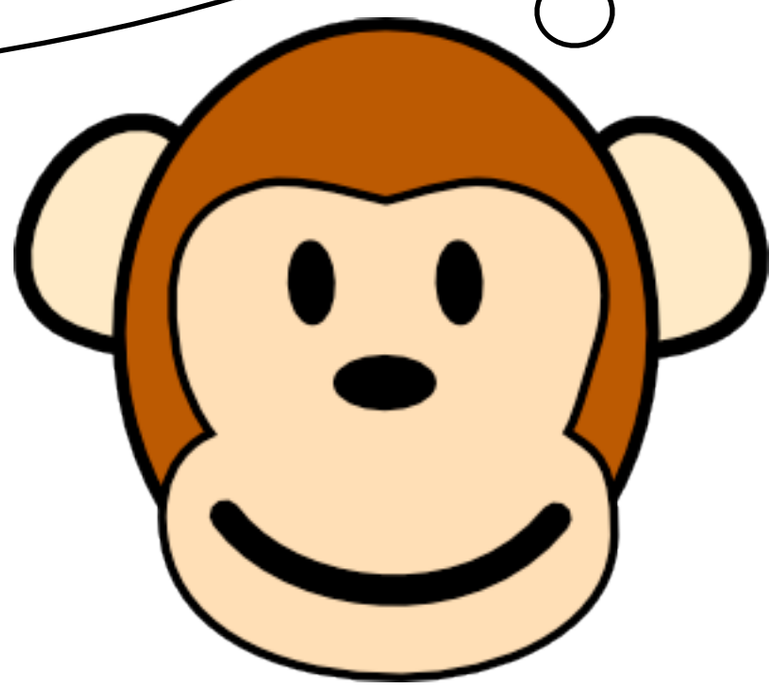


(Very) simple model of signalling

- Mapping between *meanings* and *signals*

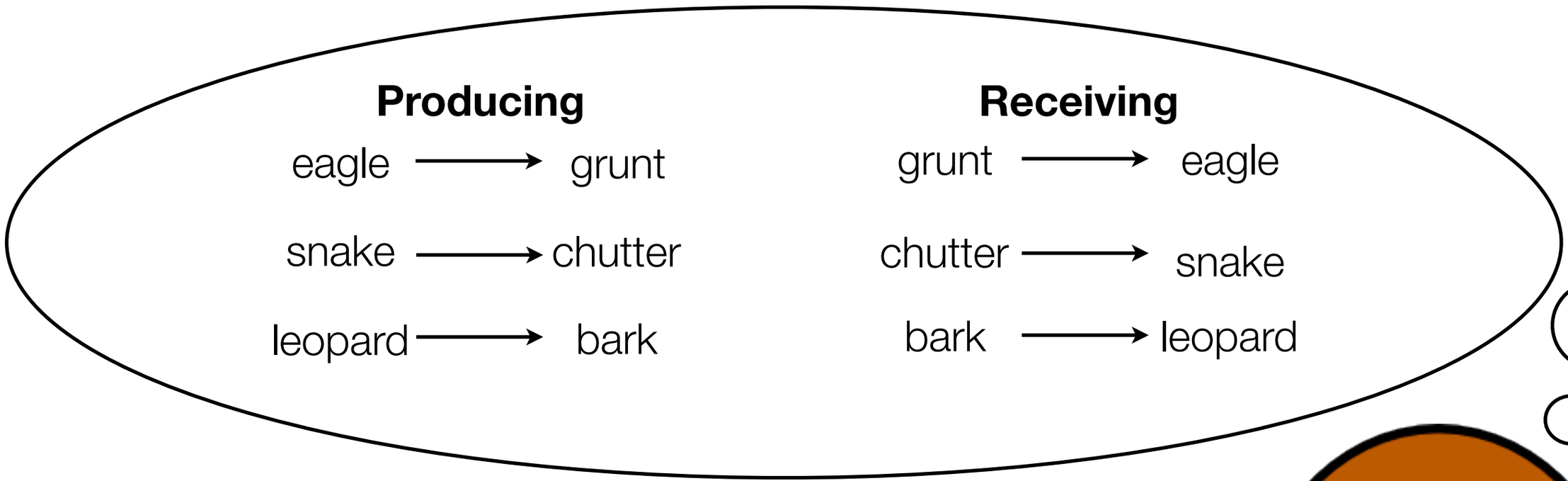


- How does this evolve?



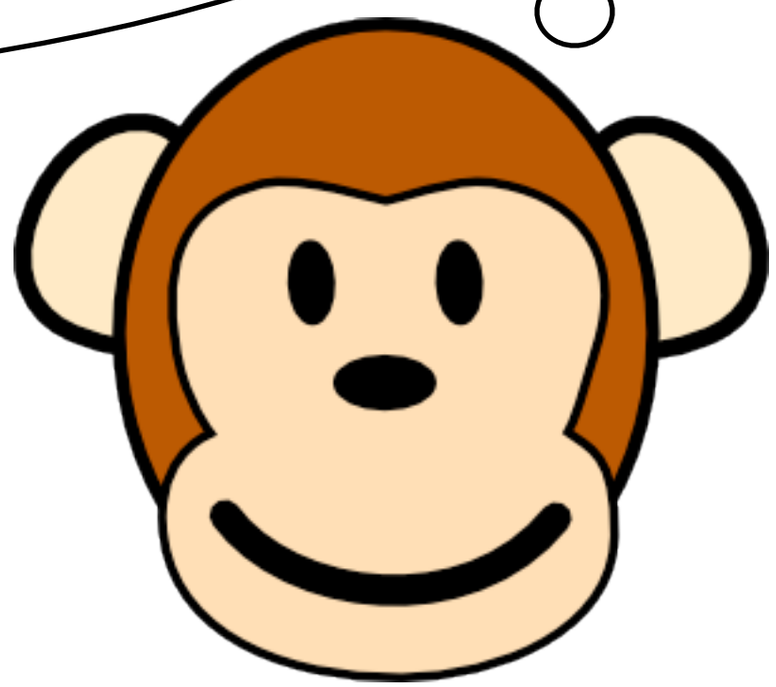
(Very) simple model of signalling

- Mapping between *meanings* and *signals*



- How does this evolve?

- What happens when two *agents* get together that have particular mappings?



How to model an agent

How to model an agent

- Need to represent the mapping between meanings and signals somehow

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

Use the matrix for production and reception

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

	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 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

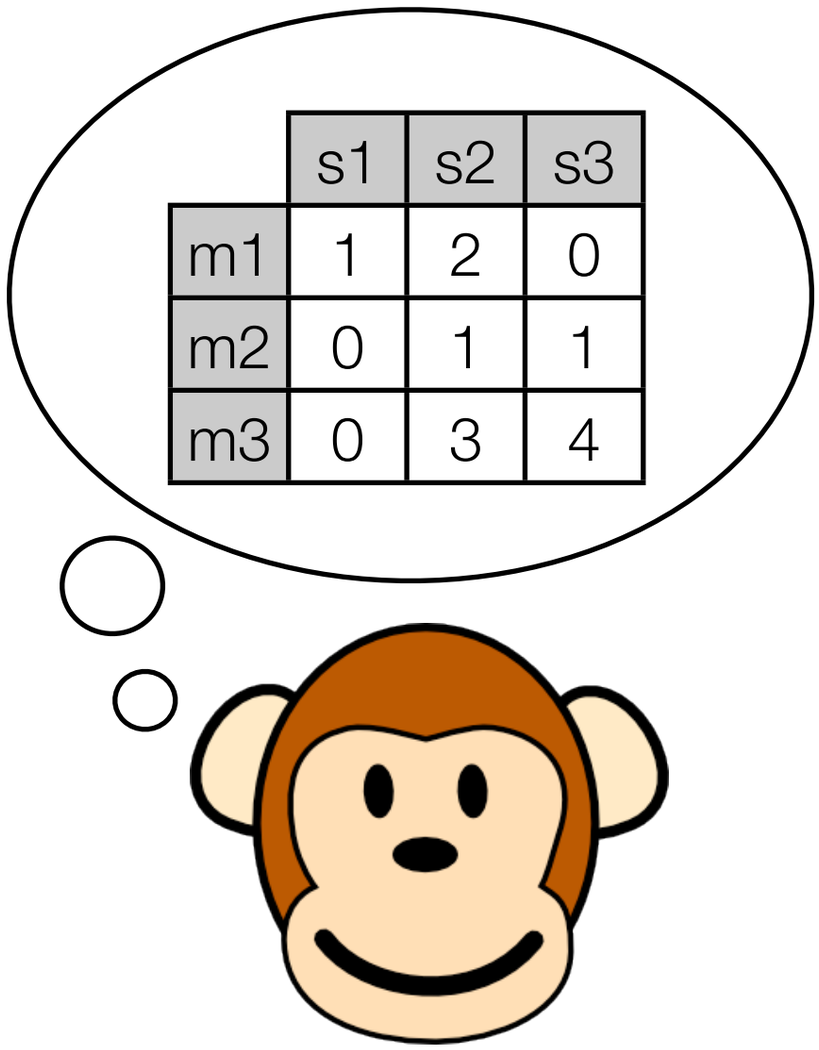
	m1	m2	m3
s1	1	0	0
s2	2	1	3
s3	0	1	4

How can we measure communication success?

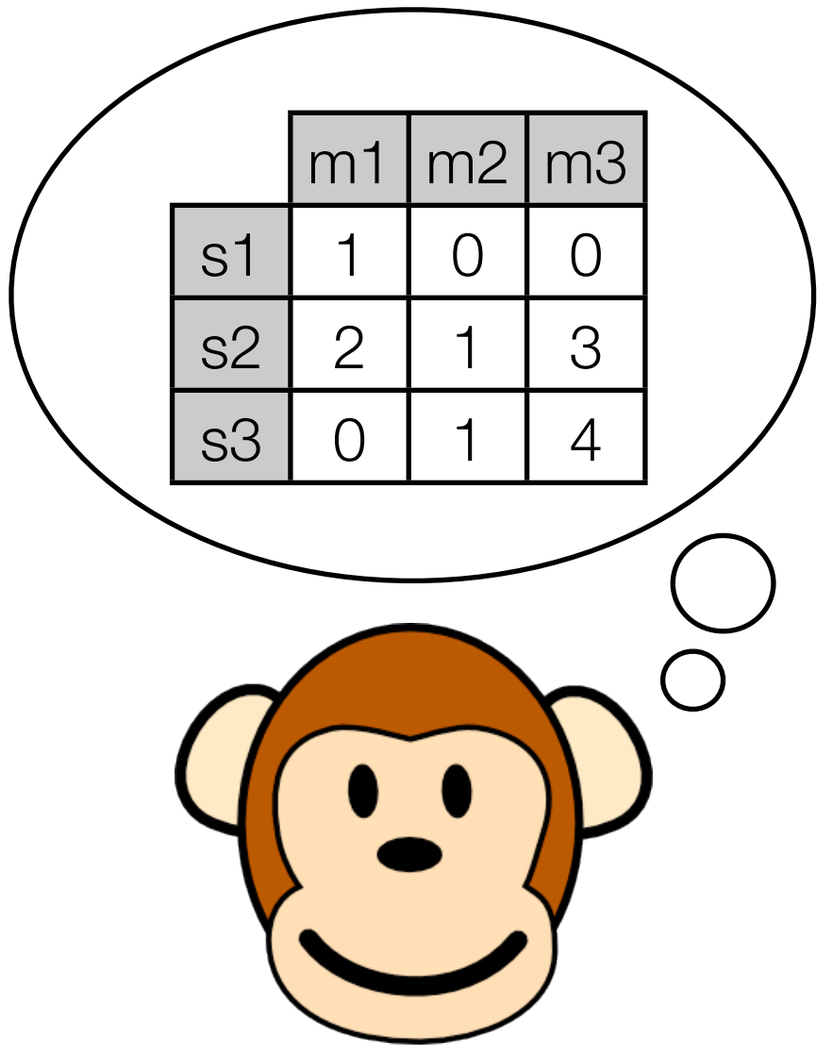
- Now we have a model of signalling, how do we measure how good a signalling system is for communication?

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

Monte Carlo simulation

Monte Carlo simulation

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

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:

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

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

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

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

Monte Carlo simulation

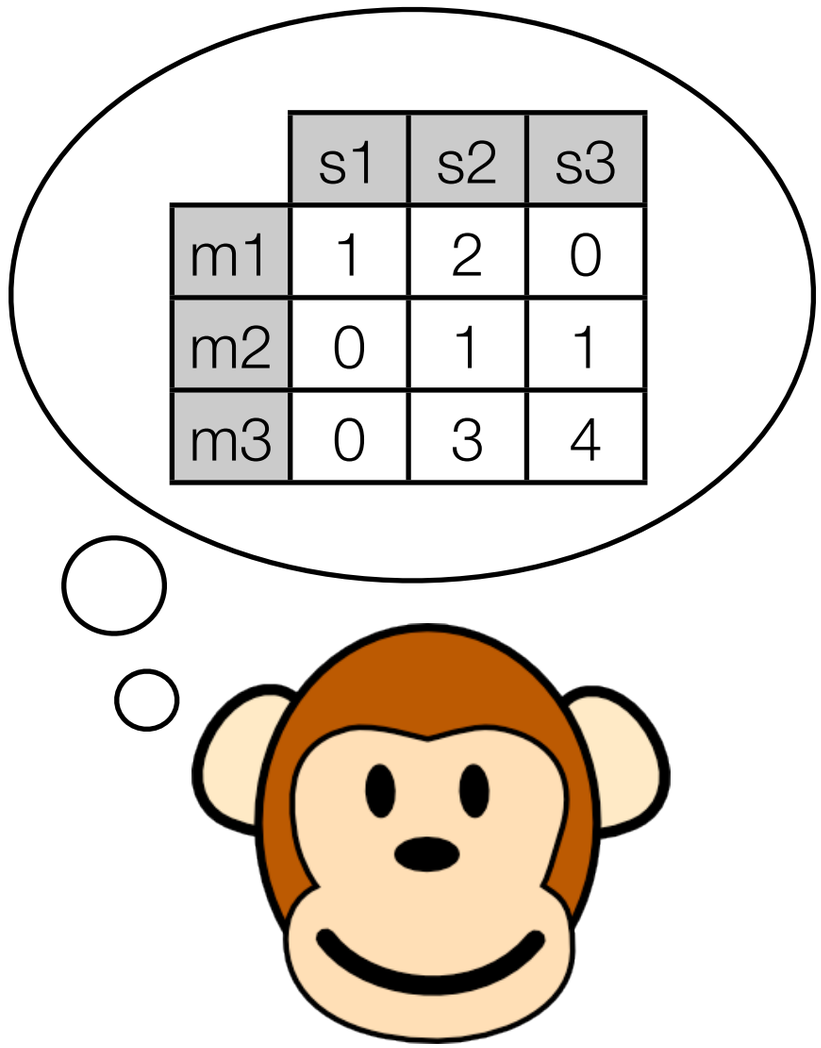
- One way: build a simulation of thousands of communication events between two agents, a producer and a receiver.

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

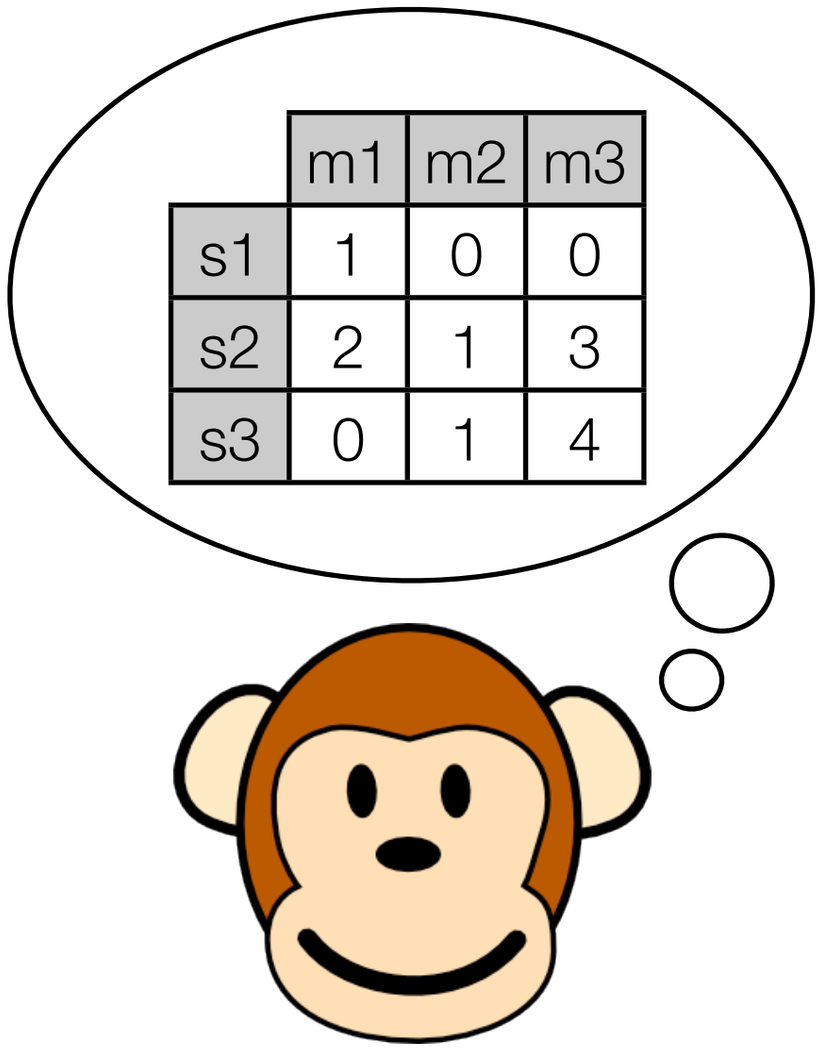
1. Pick a random meaning
2. Use winner take all to generate a signal for that meaning according to the producer's production matrix
3. Use winner take all again to see what meaning corresponds to that signal in the receiver's reception matrix
4. If the receiver's meaning is the same as the original one,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

- Repeat 1-4 thousands of times and return the proportion of these "trials" that were successful. This is your *communicative accuracy score.*

Communicative accuracy



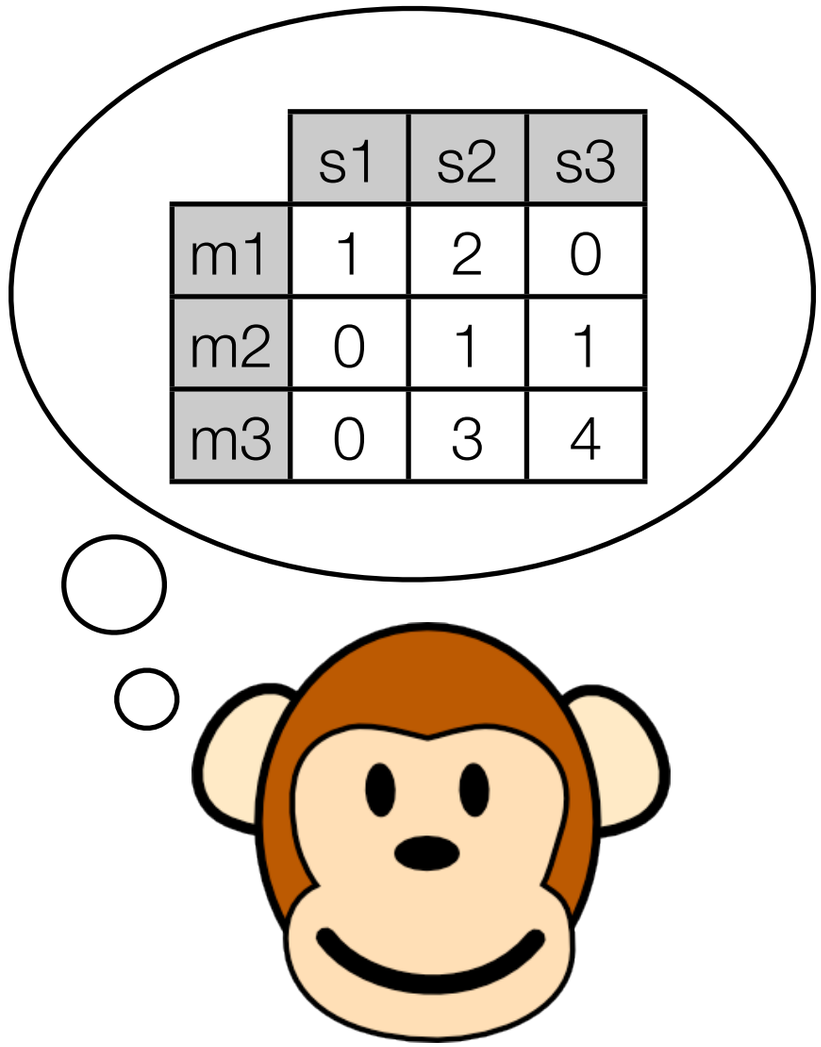
	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4



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

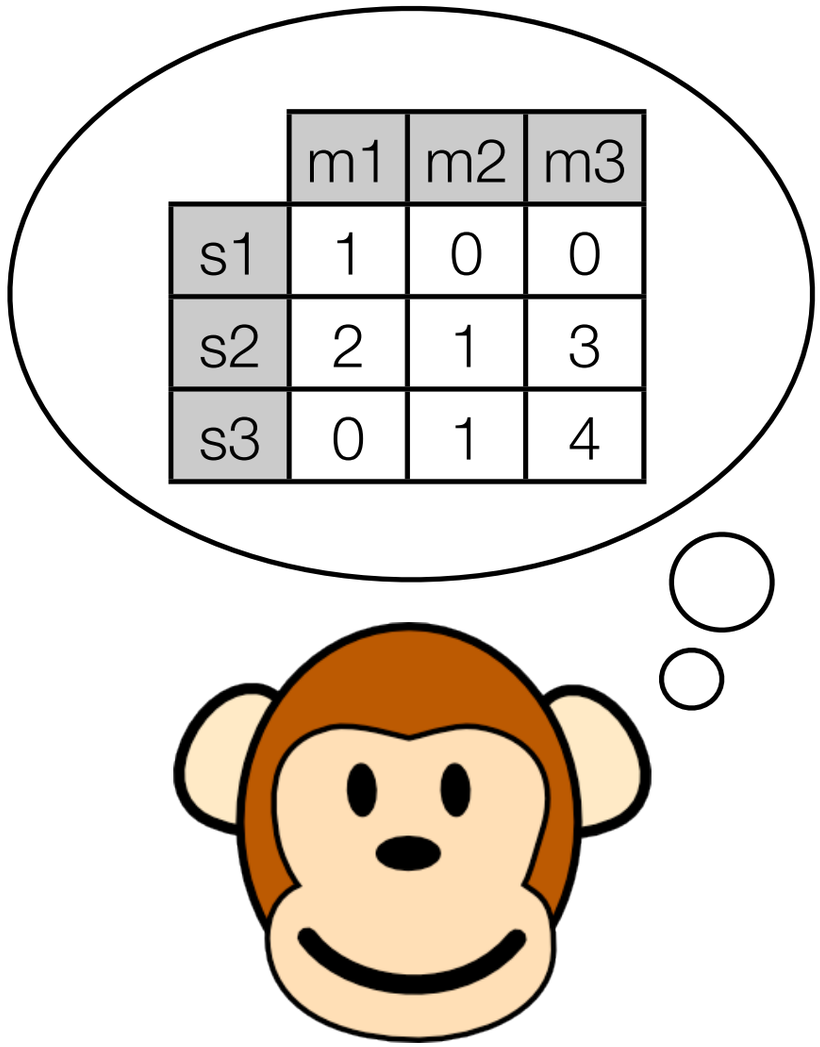
Communicative accuracy

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



Producer

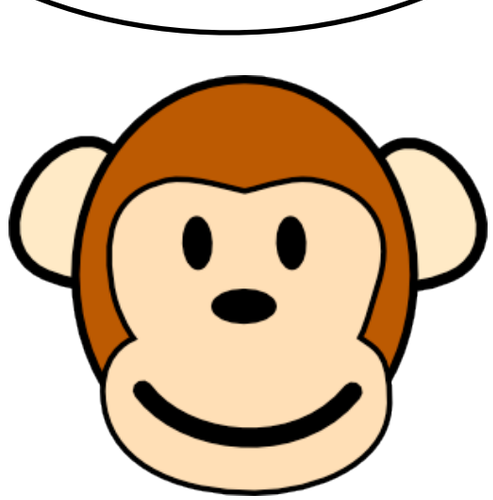
	m1	m2	m3
s1	1	0	0
s2	2	1	3
s3	0	1	4



Receiver

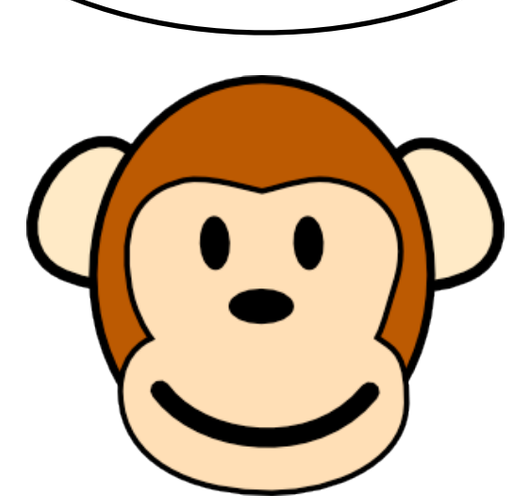
Communicative accuracy

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



Producer

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



Receiver

Communicative accuracy: 0.33

Some questions for you

Some questions for you

- If we can work out communicative accuracy “perfectly” by hand, without doing the simulation, then what is the point of the simulation?

Some questions for you

- If we can work out communicative accuracy “perfectly” by hand, without doing the simulation, then what is the point of the simulation?

- Some signalling systems are better than others. What kinds of things determine how good a signalling system is? How do animals end up with the best ones?

Some questions for you

- If we can work out communicative accuracy “perfectly” by hand, without doing the simulation, then what is the point of the simulation?

- Some signalling systems are better than others. What kinds of things determine how good a signalling system is? 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?

Some questions for you

- If we can work out communicative accuracy “perfectly” by hand, without doing the simulation, then what is the point of the simulation?

- Some signalling systems are better than others. What kinds of things determine how good a signalling system is? 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?

One way to model matrices in Python

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

One way to model matrices in Python

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

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

One way to model matrices in Python

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

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

- How would you access the row of association strengths for m1? m2? m3?

One way to model matrices in Python

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

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

- How would you access the row of association strengths for m1? m2? m3?
- How would you access the strength of association between m1 and s1?

One way to model matrices in Python

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

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

- How would you access the row of association strengths for m1? m2? m3?
- How would you access the strength of association between m1 and s1?
- How can you tell if this is a production or a reception matrix?