While you are waiting...

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Simulating Language
Lecture 8: Learning bias considered

Kenny Smith

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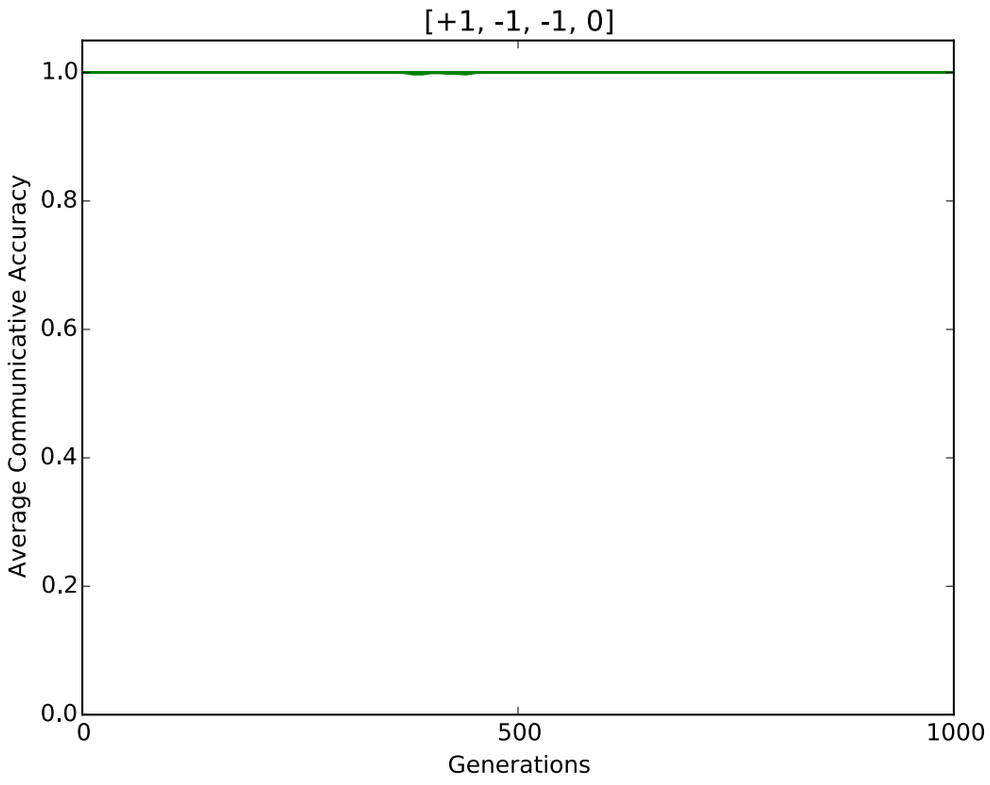
Deadline for questions about the assignment: midnight tonight

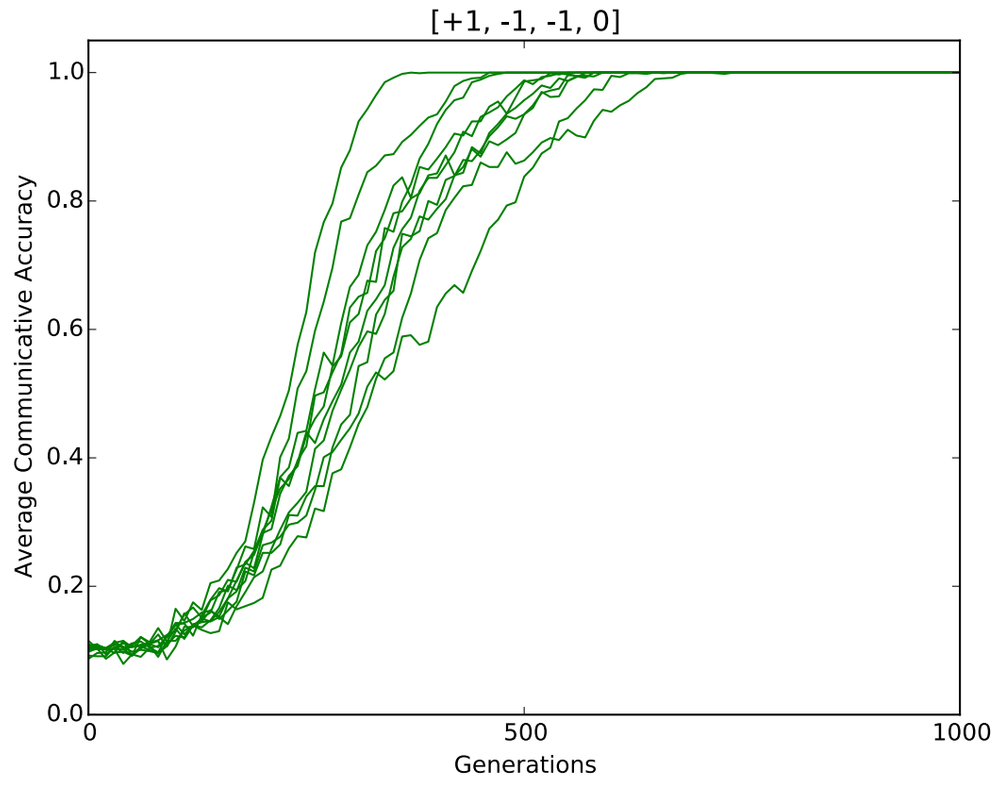
Rule: [1, -1, -1, 0]

Passes acquisition test? **Yes**

Maintenance: **Yes**



Construction: **Yes**



Rule: [1, 0, 0, 0]

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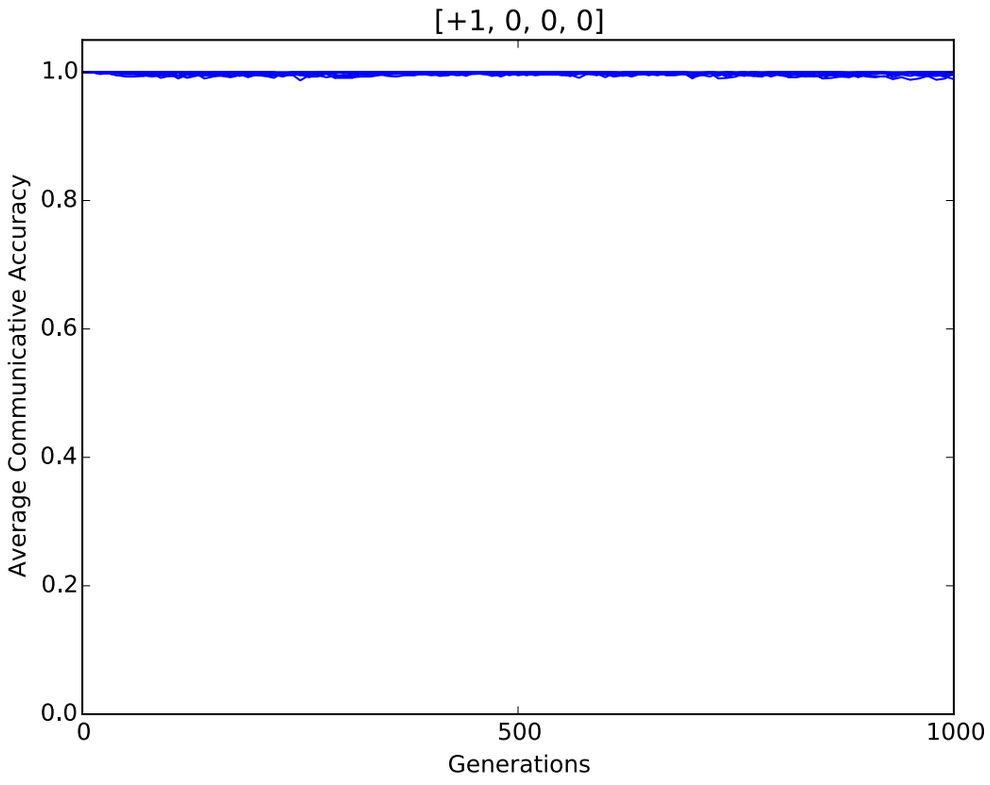
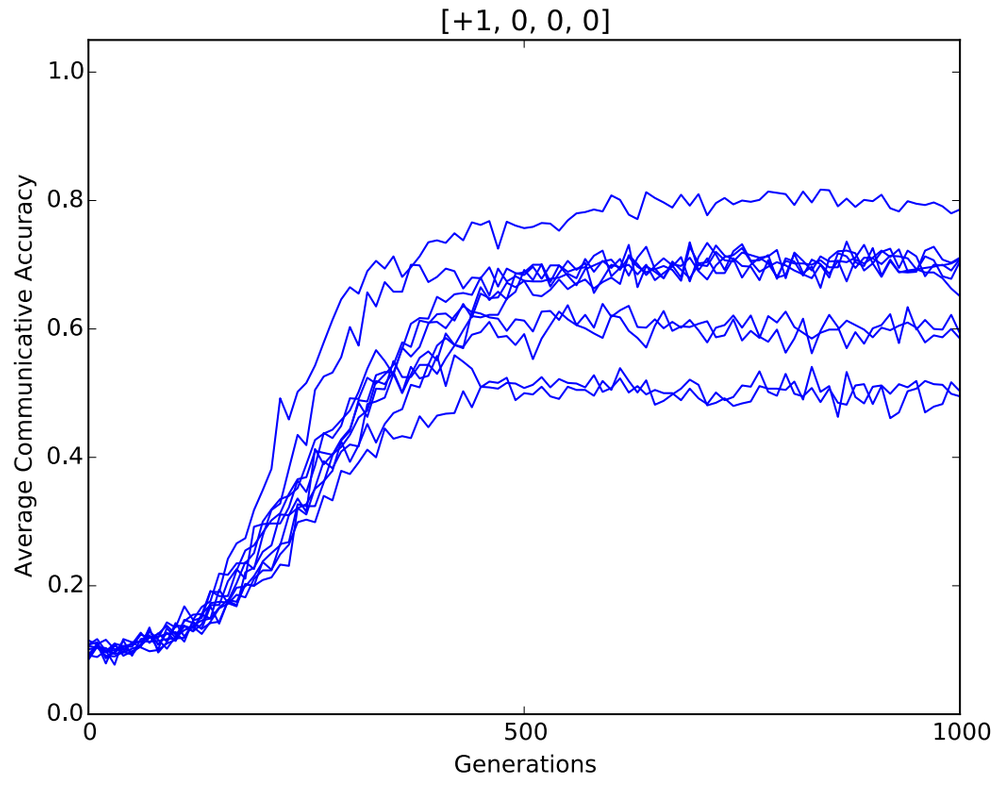
Maintenance: **Yes**



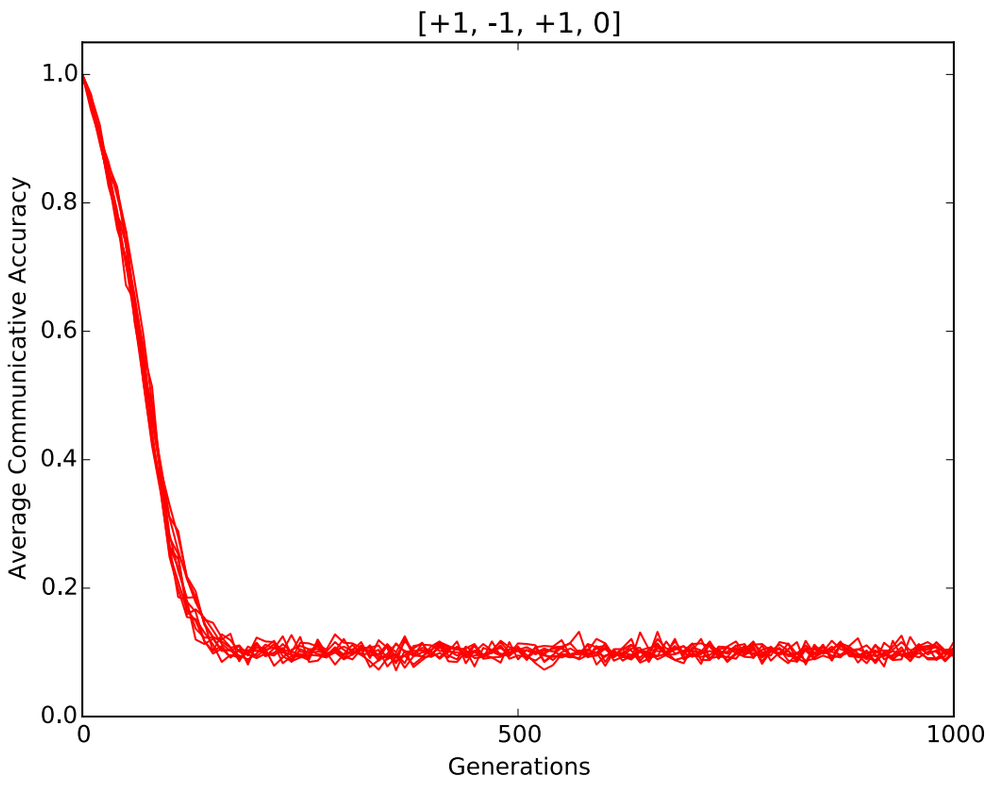
Construction: **No**



Rule: [1, -1, 1, 0]

Passes acquisition test? **Yes**

Maintenance: **No**



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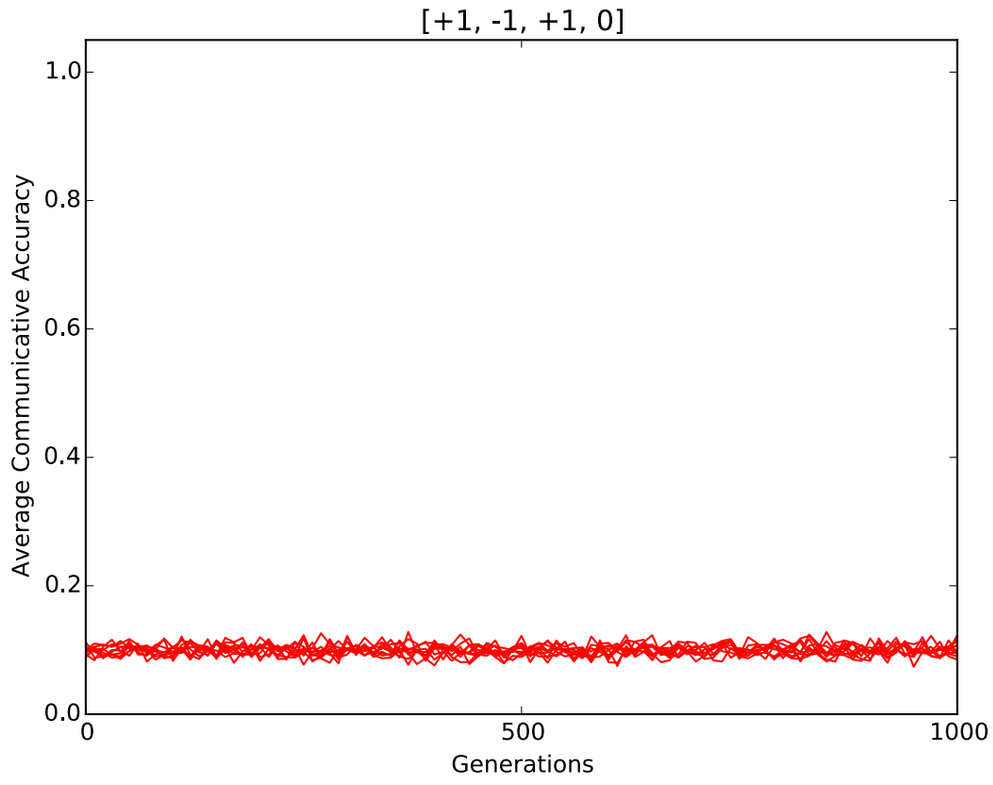
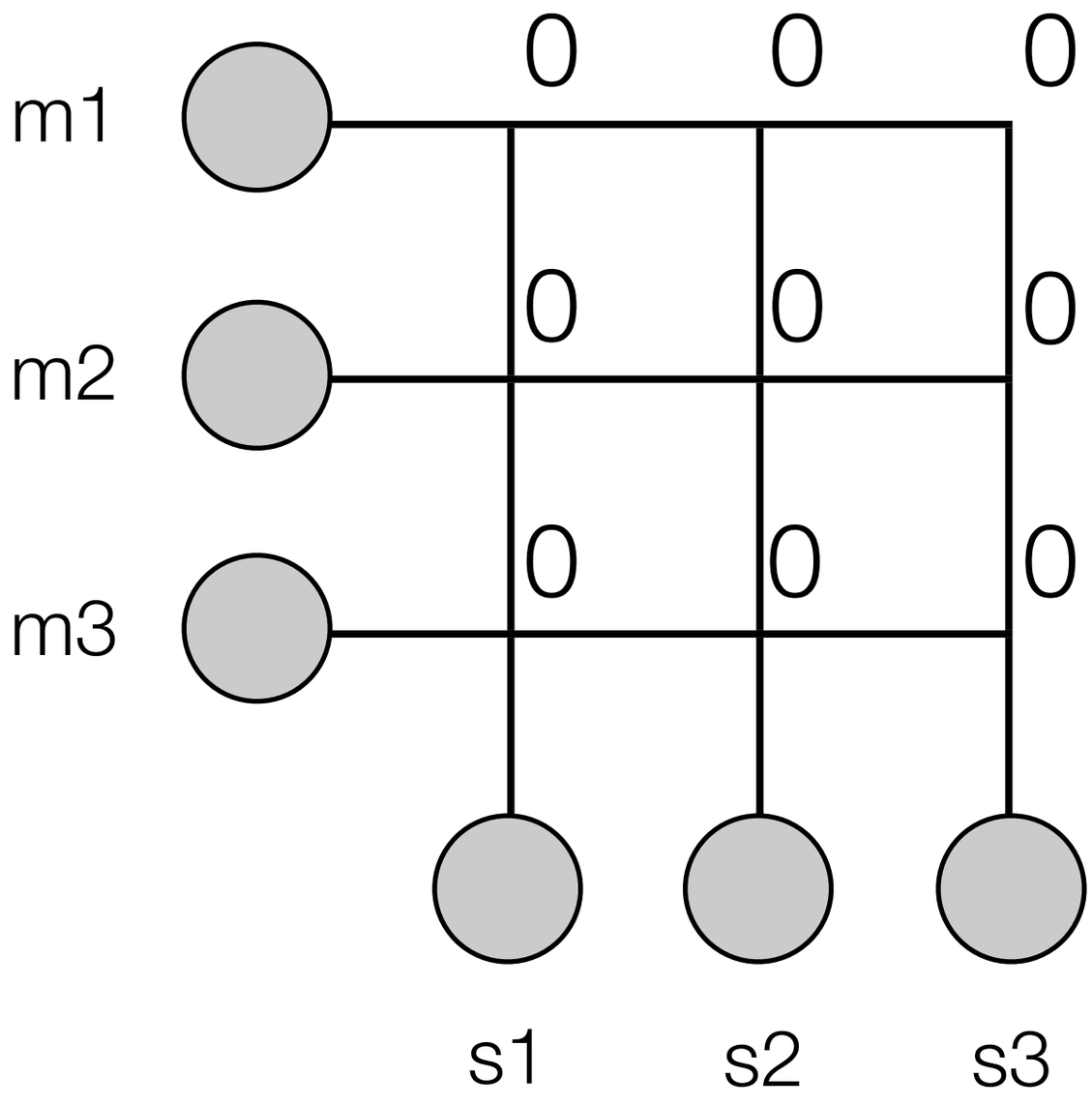


Bias

- Different weight update rules correspond to different ways of learning
- They come with different *biases*
    - Although that's not immediately obvious just from looking at acquisition
- Population's language (in this case, just a vocabulary really) evolves to fit these biases
- Biases are a consequence of α, β, γ and δ
- But what exactly are these different biases?

Working out bias

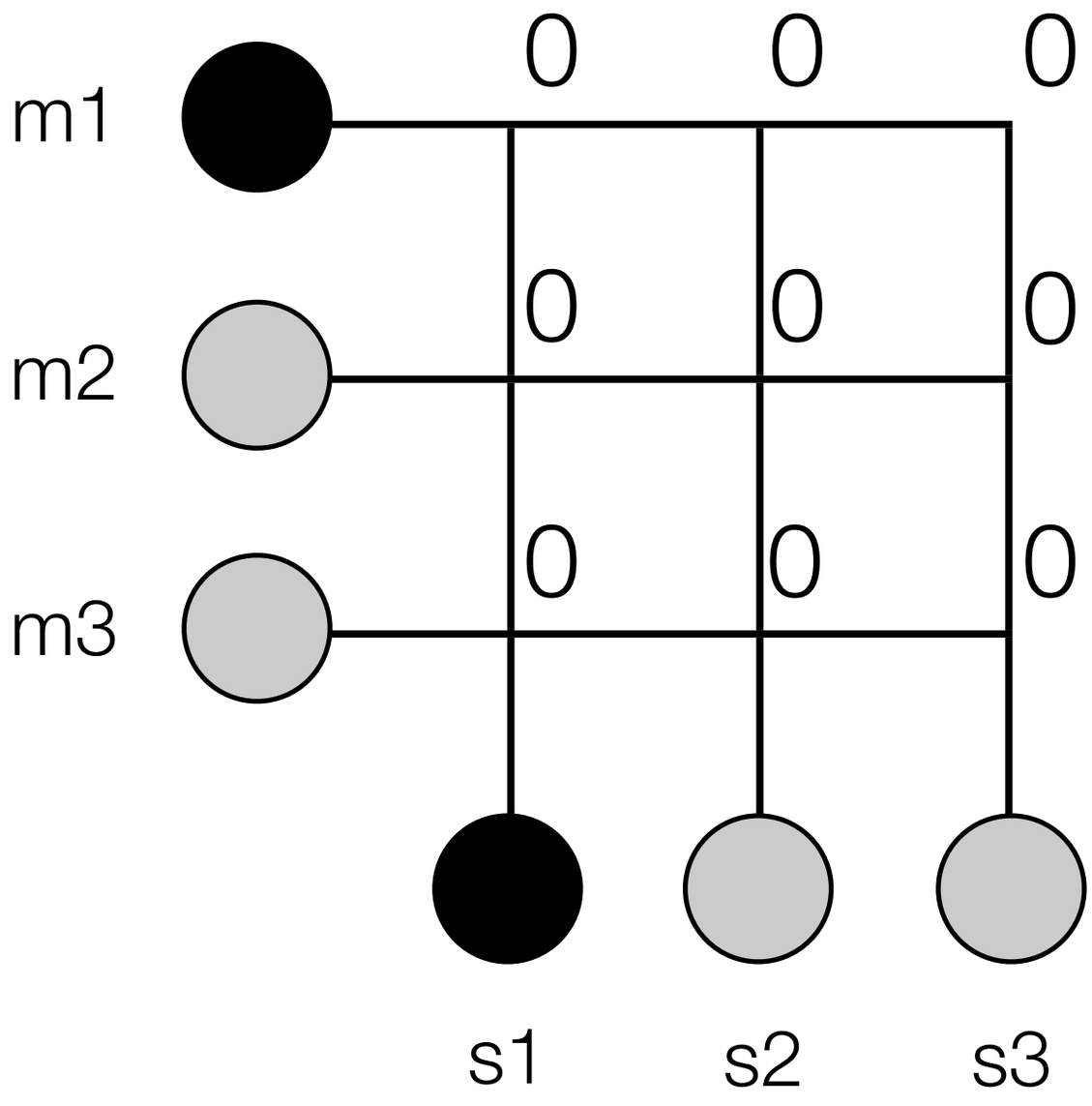
- A constructor rule: [+1, -1, -1, +1]



Working out bias

- A constructor rule: [+1, -1, -1, +1]

Observation:
m1→s1



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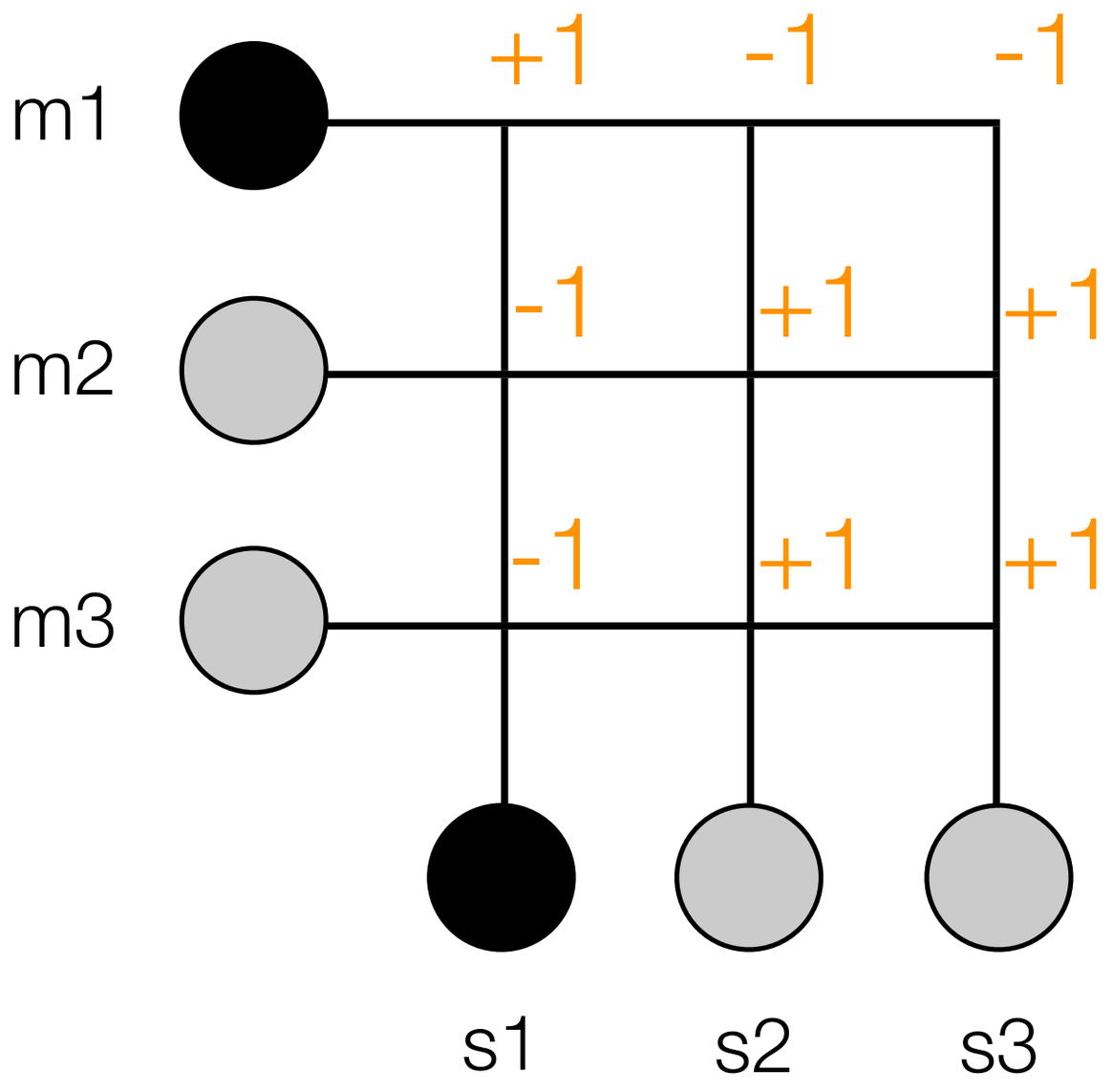

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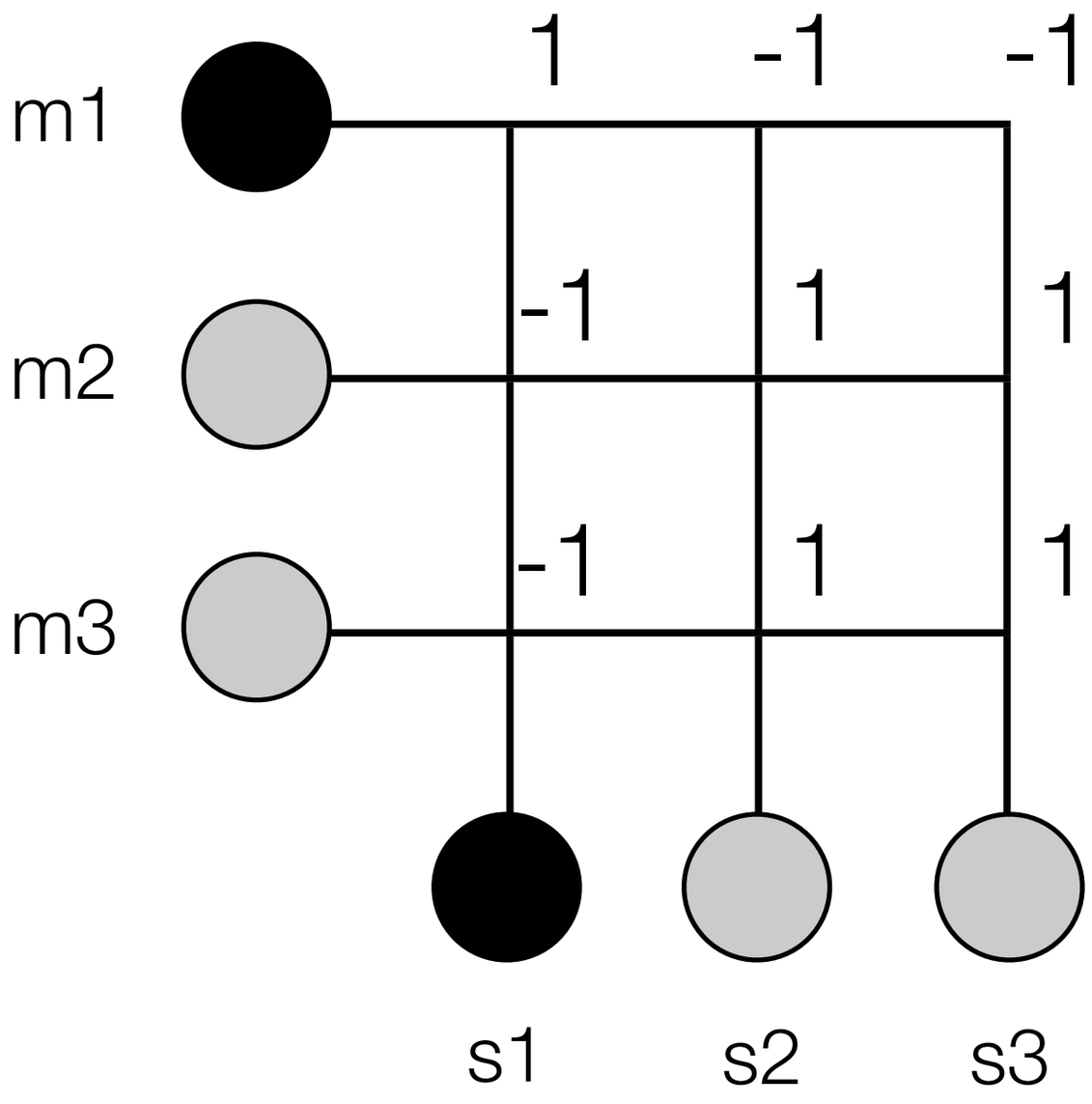
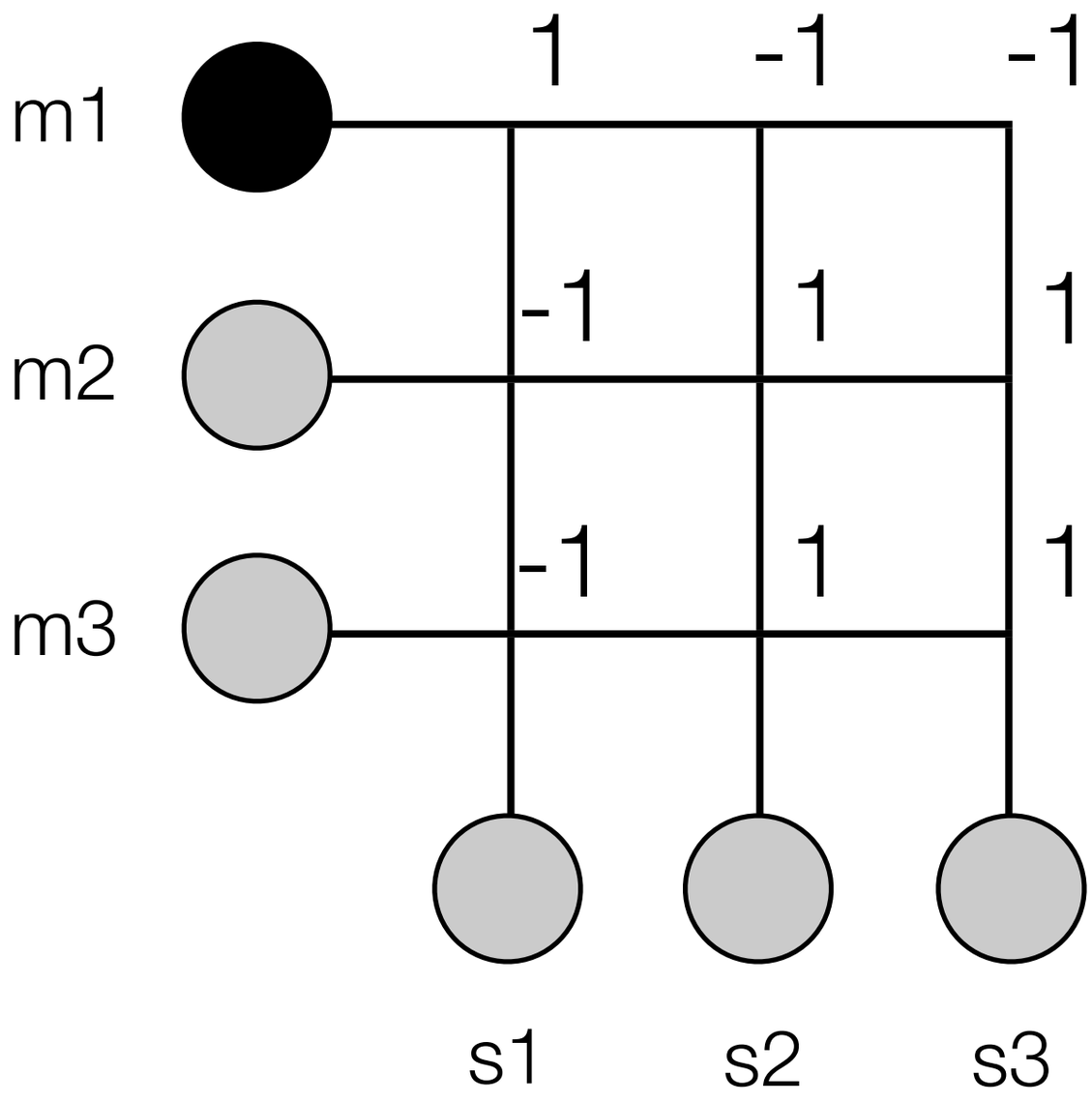


Working out bias

- A constructor rule: [+1, -1, -1, +1]

Production:

m1→?



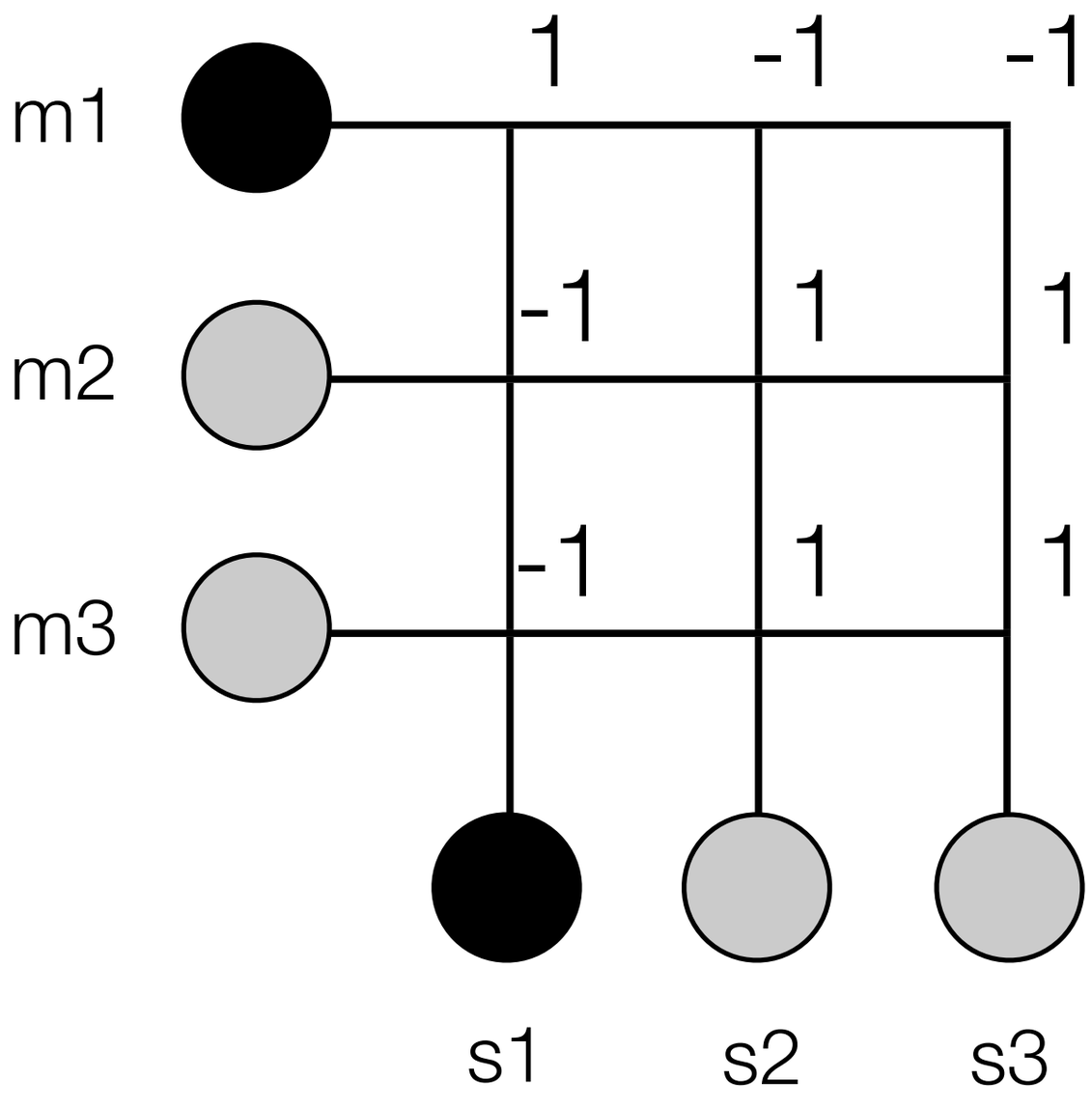
Working out bias

- A constructor rule: [+1, -1, -1, +1]

Production:

m1→s1

(*not* s2 or s3)

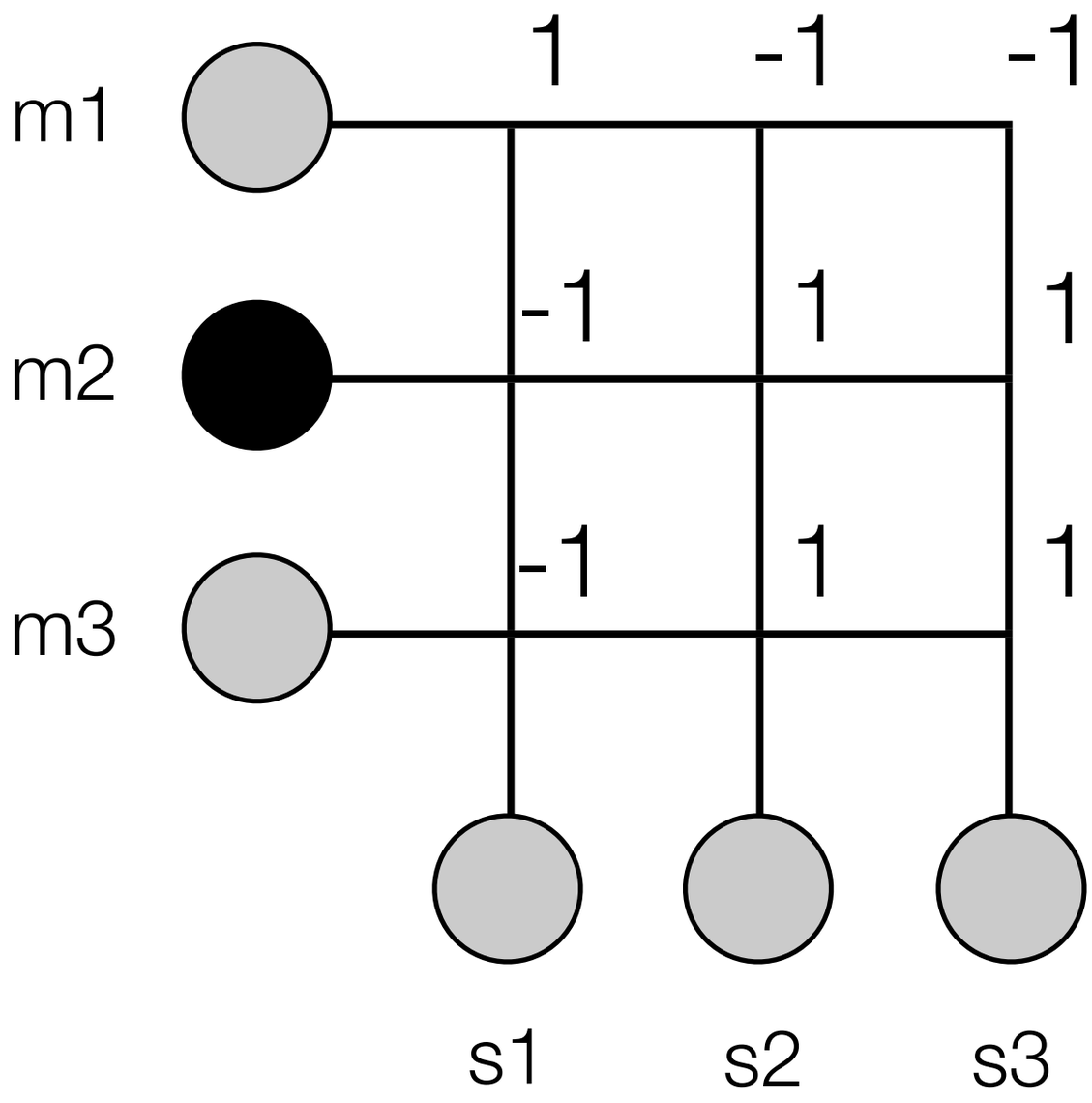


Working out bias

- A constructor rule: [+1, -1, -1, +1]

Production:

m2→?



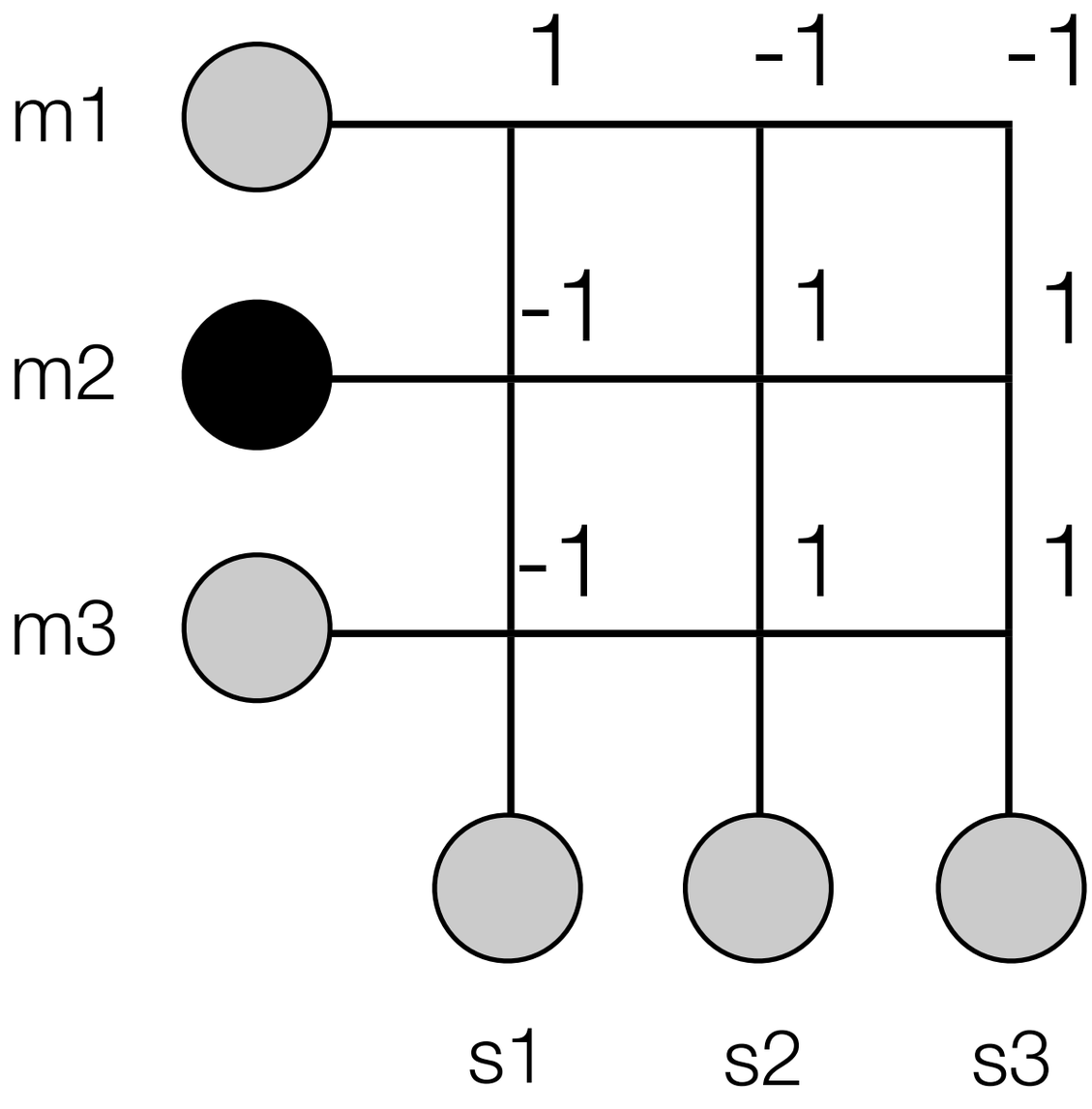
Working out bias

- A constructor rule: [+1, -1, -1, +1]

Production:

m2→s2 or s3

(*not* s1)



Working out bias

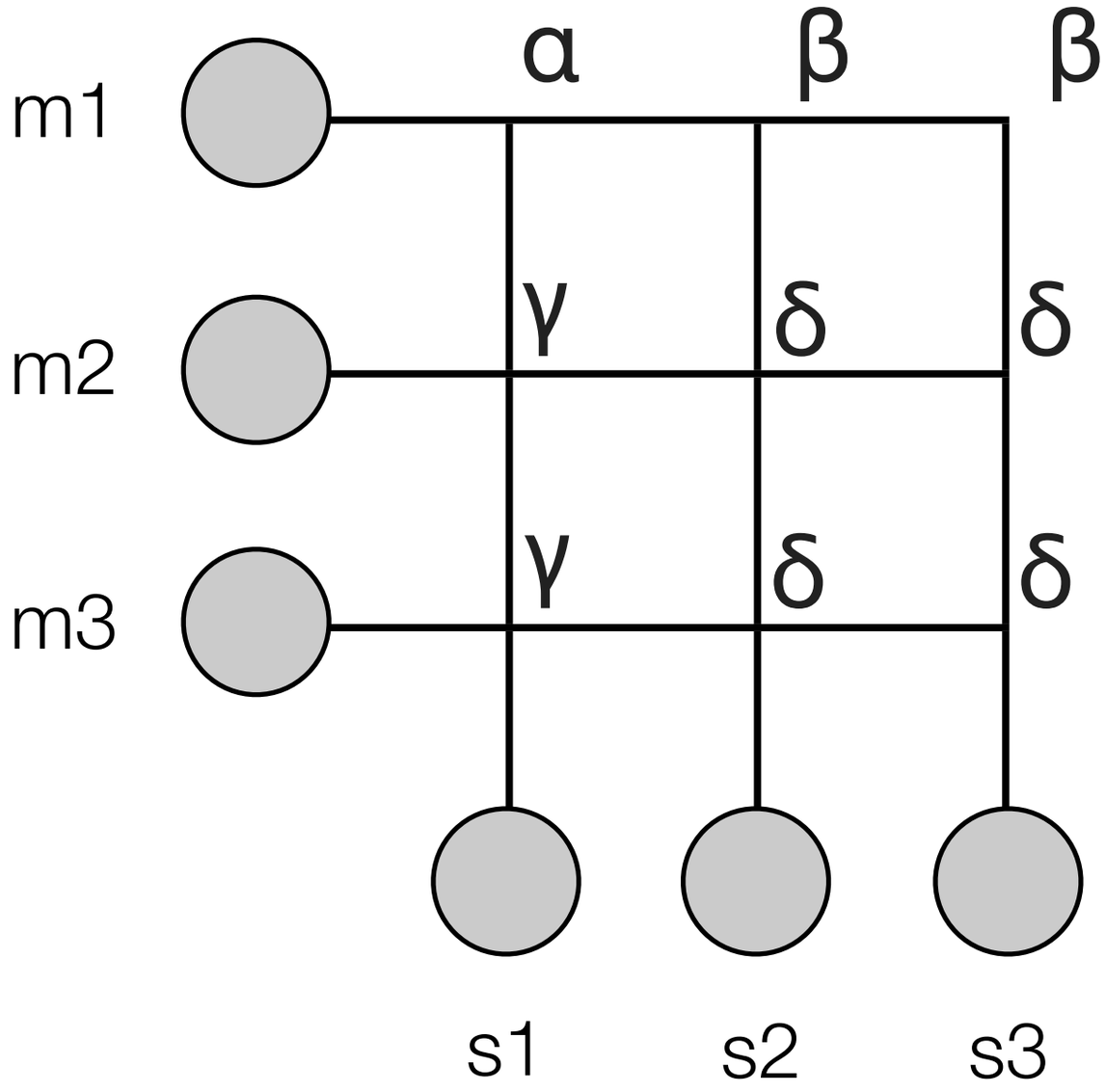
- Constructors in general: α > β & δ > γ
  After one exposure to m1→s1

Production:

m1→s1

m2→s2 or s3

m3→s2 or s3

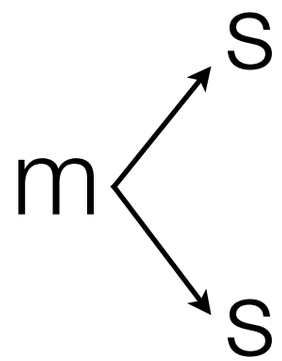


The constructor bias

- Constructors don't like:

- One meaning to multiple signals

  because α > β
  bias against synonymy



- Multiple meanings to one signal

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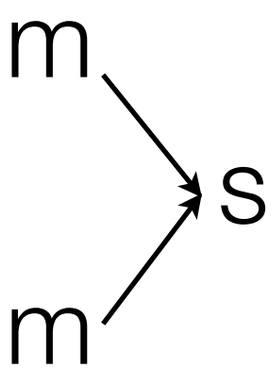
  bias against homonymy



The constructor bias

- Constructors biased in favour of **one-to-one** mappings between meanings and signals

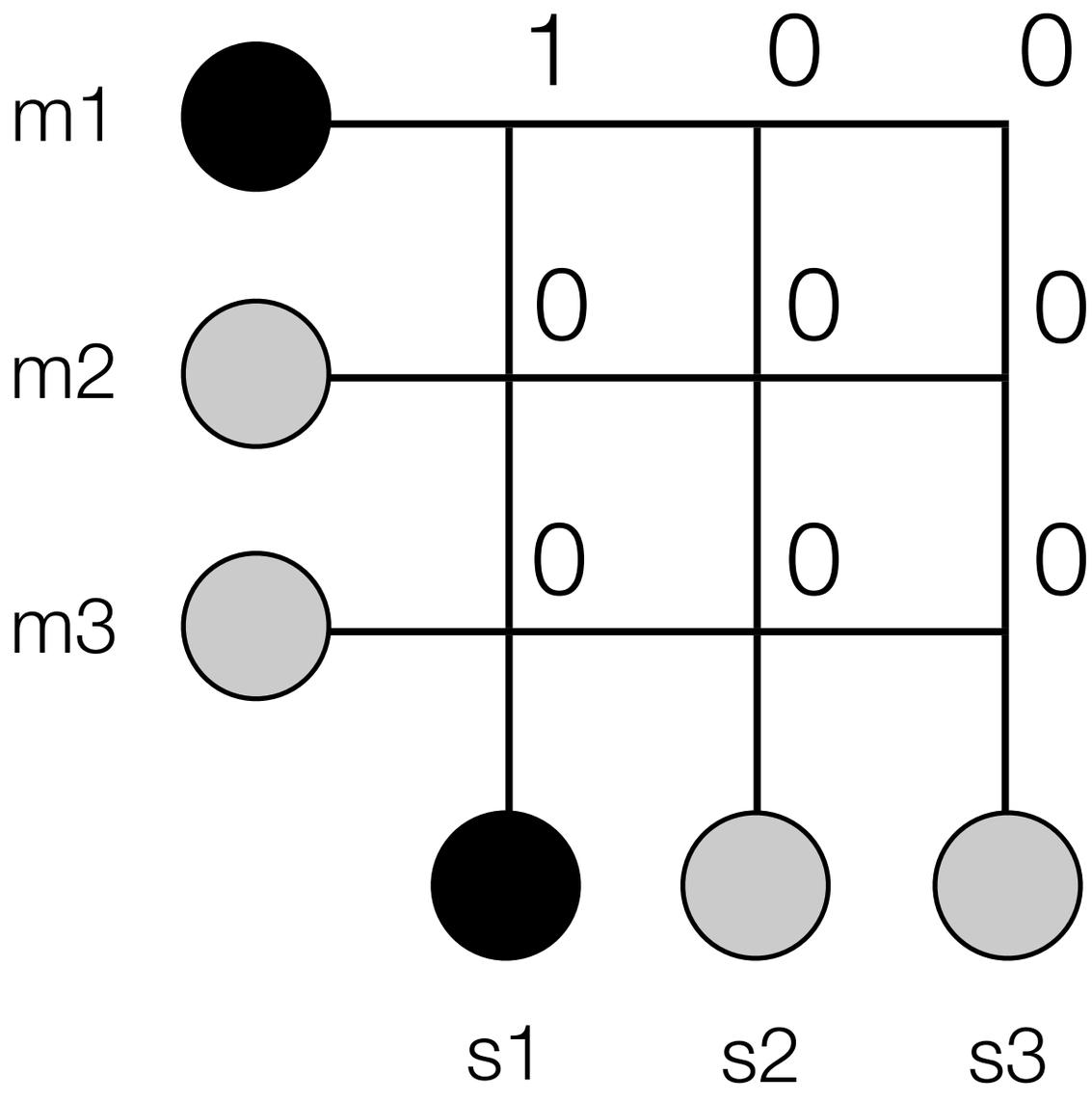
- Population's vocabulary changes over time to match this bias

- One-to-one systems happen to be optimal for communication

Working out bias

- A maintainer rule: [+1, 0, 0, 0]

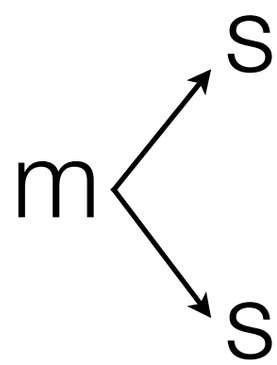
Observation:
m1→s1



The maintainer bias

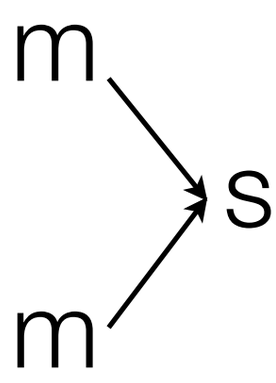
- Biased against synonymy

  because α > β



- **Neutral** with respect to homonymy

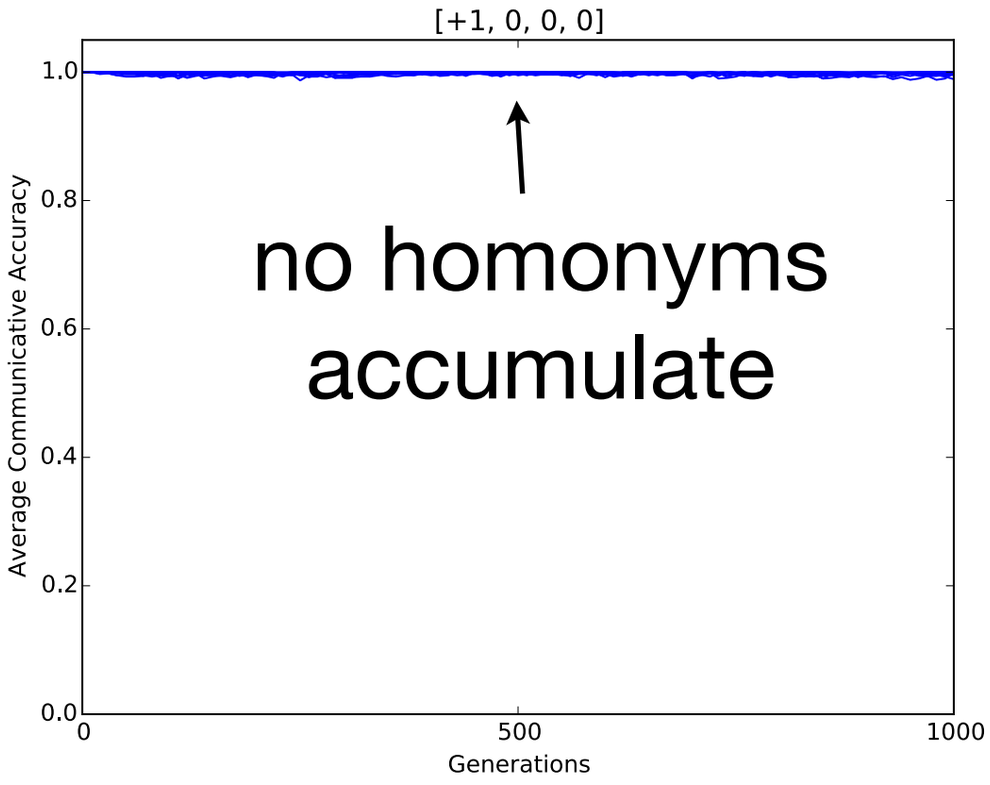
  because δ = γ



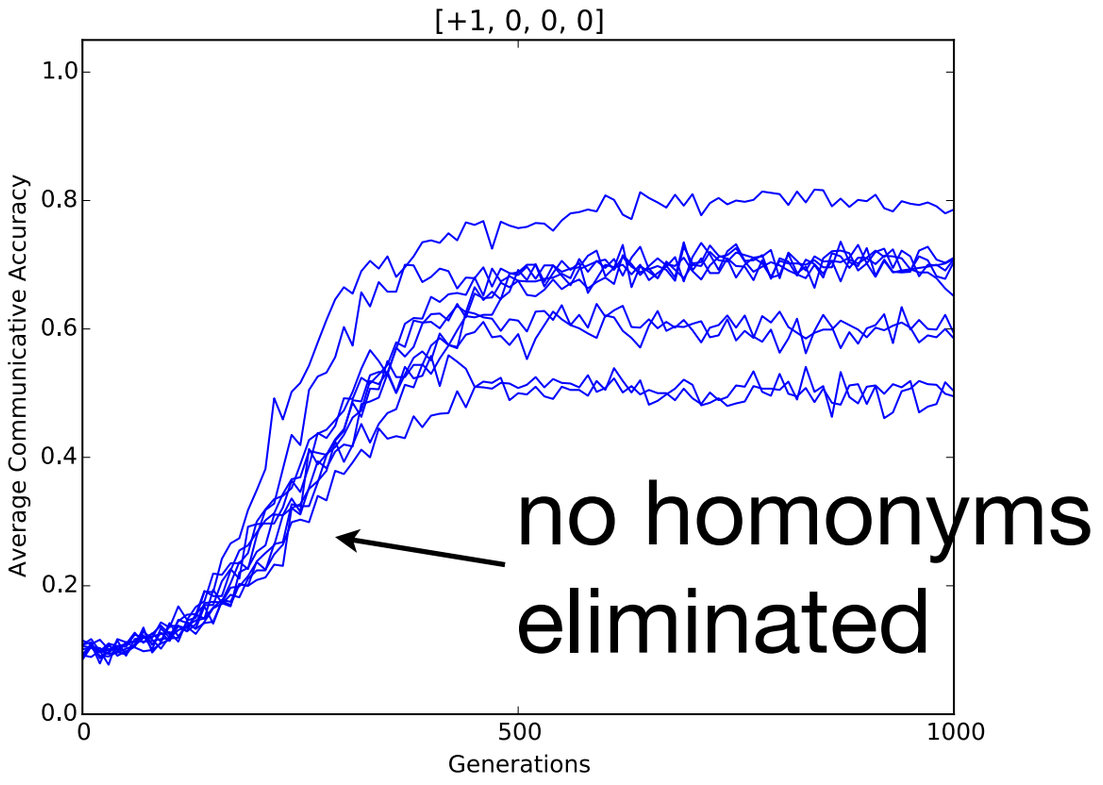
Rule: [1, 0, 0, 0]

Passes acquisition test? **Yes**

Maintenance: **Yes**



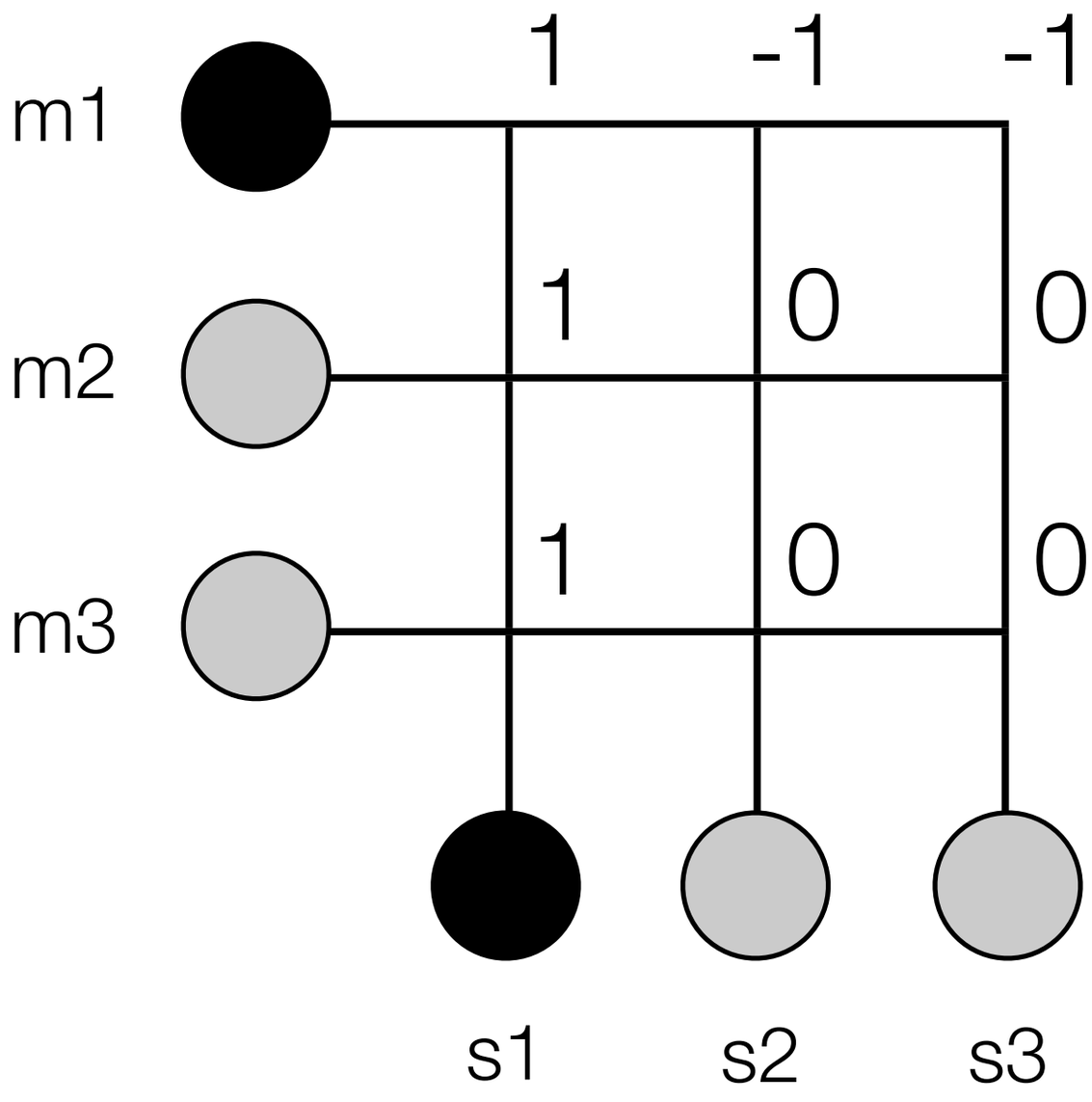
Construction: **No**



Working out bias

- A learner rule: [+1, -1, 1, 0]

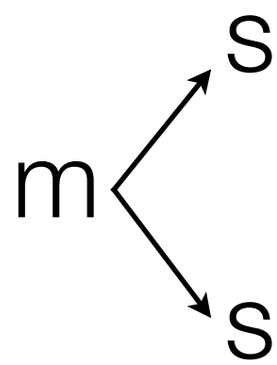
Observation:
m1→s1



The learner bias (in most cases)

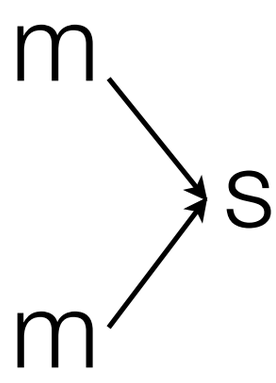
- Biased against synonymy

  because $\alpha > \beta$



- Biased *in favour* of homonymy

  because $\delta < \gamma$



Rule: [1, -1, 1, 0]

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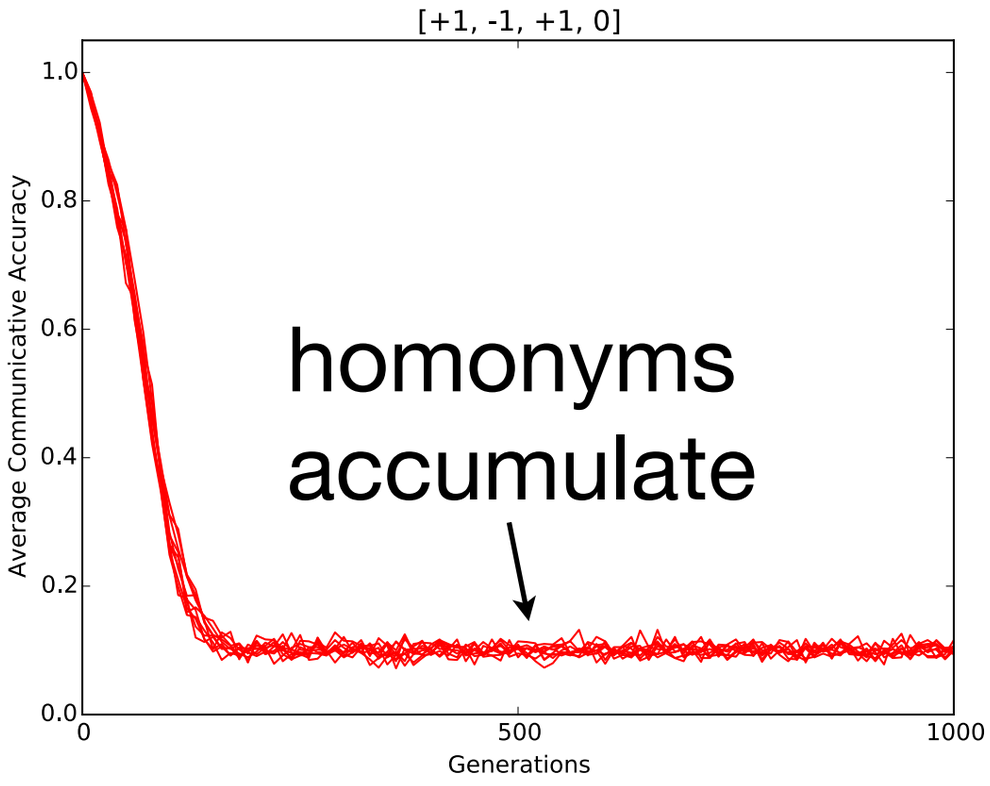
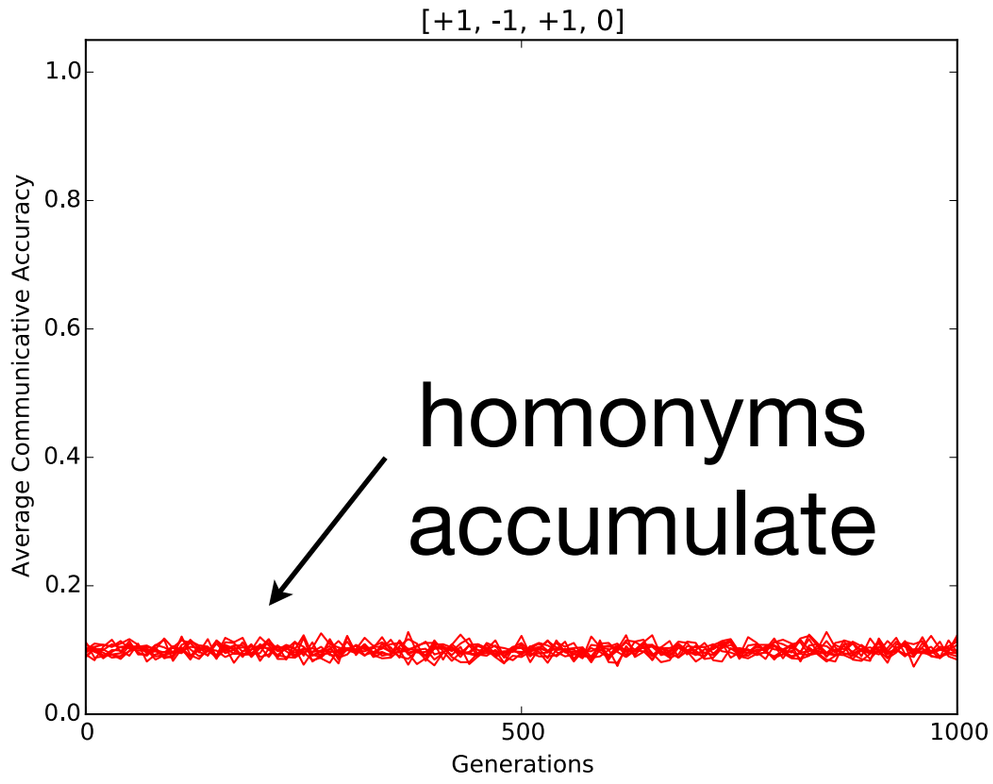


Construction: **No**



What about this rule? [0,-1,0,+1]

- A: it can neither maintain or construct
- B: it can maintain but not construct
- C: it can construct but not maintain
- D: it can maintain and construct

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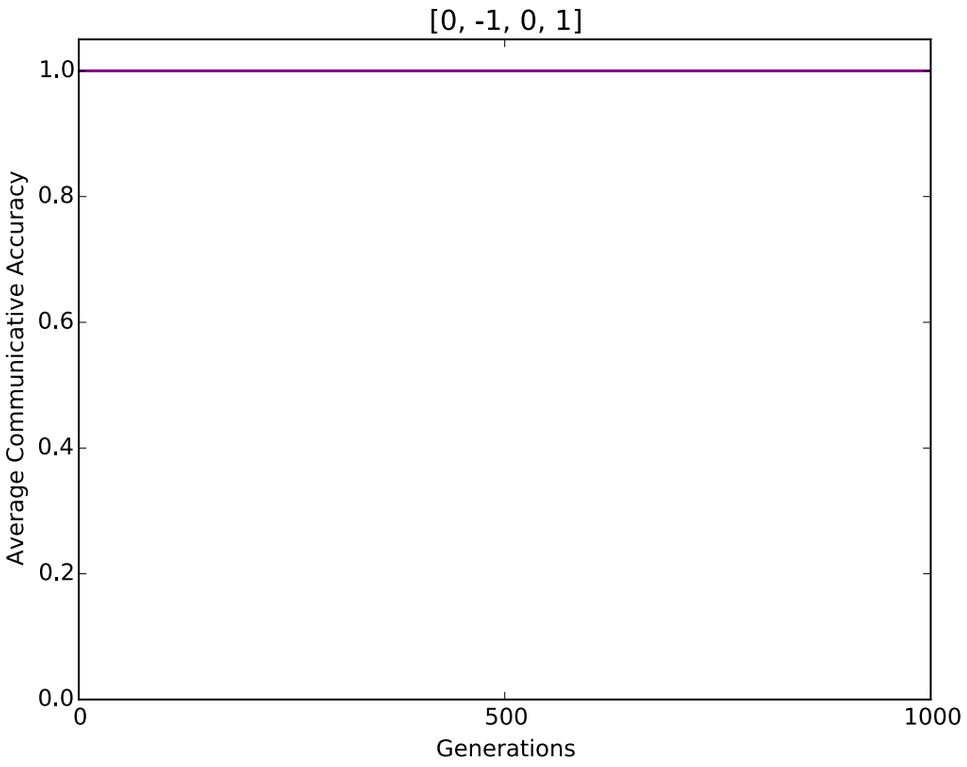
Rule: [0, -1, 0, +1]

Passes acquisition test? **Yes**

Maintenance: **Yes**



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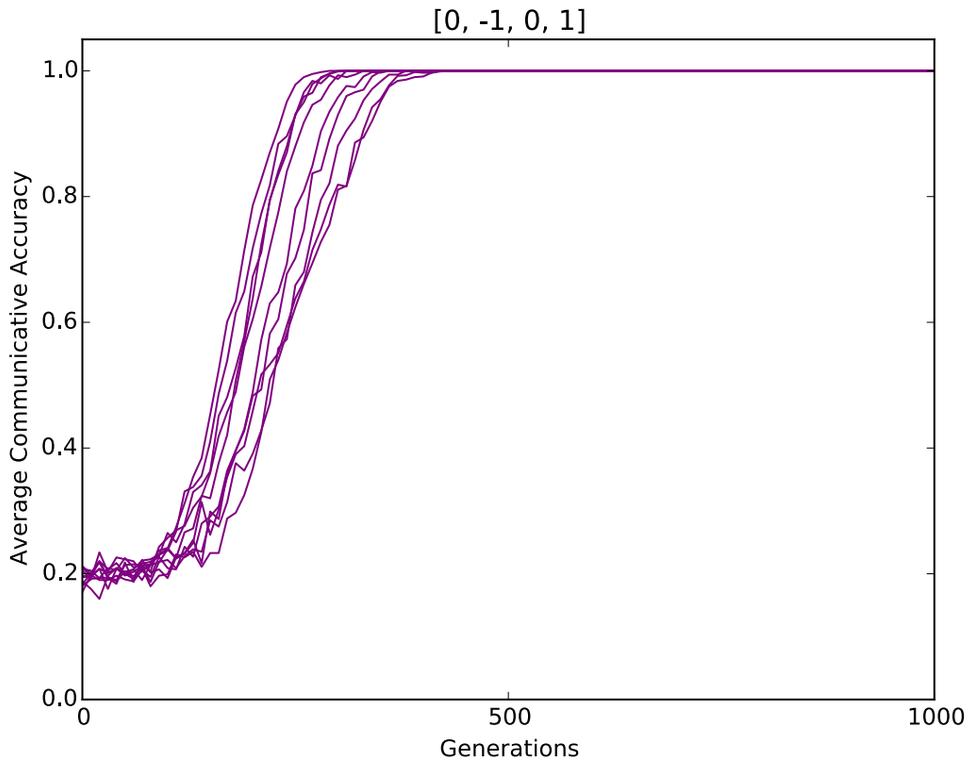

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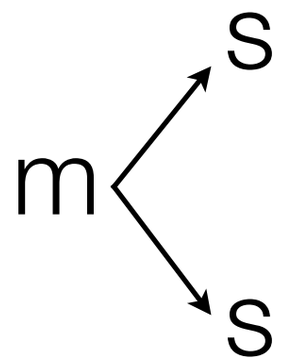
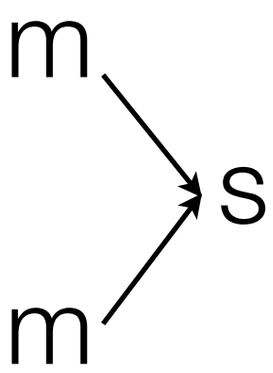


- Multiple meanings to one signal

  because δ > γ
  bias against homonymy



What about real humans?

- Experiment on children's learning bias
  Markman & Wachtel (1988) on synonymy

"Show me the fendle."

- Children pick the unfamiliar object given an unfamiliar word

Anti-synonymy bias (Mutual Exclusivity)

Before

banana

???

After (two possibilities)

banana

fendle

Homonymy bias (Doherty 2004)

- “... at the zoo, they saw a strange tapir from Brazil. Hamish thought the tapir’s long nose looked funny”

“Which one is the tapir in this story?”

Homonymy bias (Doherty 2004)

- "... at the zoo, they saw a strange **cake** from Brazil. Hamish thought the **cake's** long nose looked funny"

"Which one is the **cake** in this story?"

Anti-homonymy bias

Before

cake

???

After (two possibilities)

cake

???

Children's learning biases

- Children don't like:
    - synonymy
    - homonymy
- They have the same biases as constructors in our simple model
- Populations of constructors evolve optimal communication systems
- Our model would predict that human vocabularies would be pushed in this direction **simply through iterated learning**, without additional functional pressures

Summary of the story so far, and what comes next

- Signalling systems (and languages) can evolve as a result of their transmission
    - We can model this
- The **biases** of learners shapes what evolves
- This potentially allows us to link findings about biases in learning at the individual level to predictions / observations about language at the population level
    - But caution (or better, a model) is required - the acquisition test here was misleading
- **Next up:** a class of models that allow us to be very clear and very precise about bias

An excellent question from Thursday's lab

"So, is human language optimal for communication?"

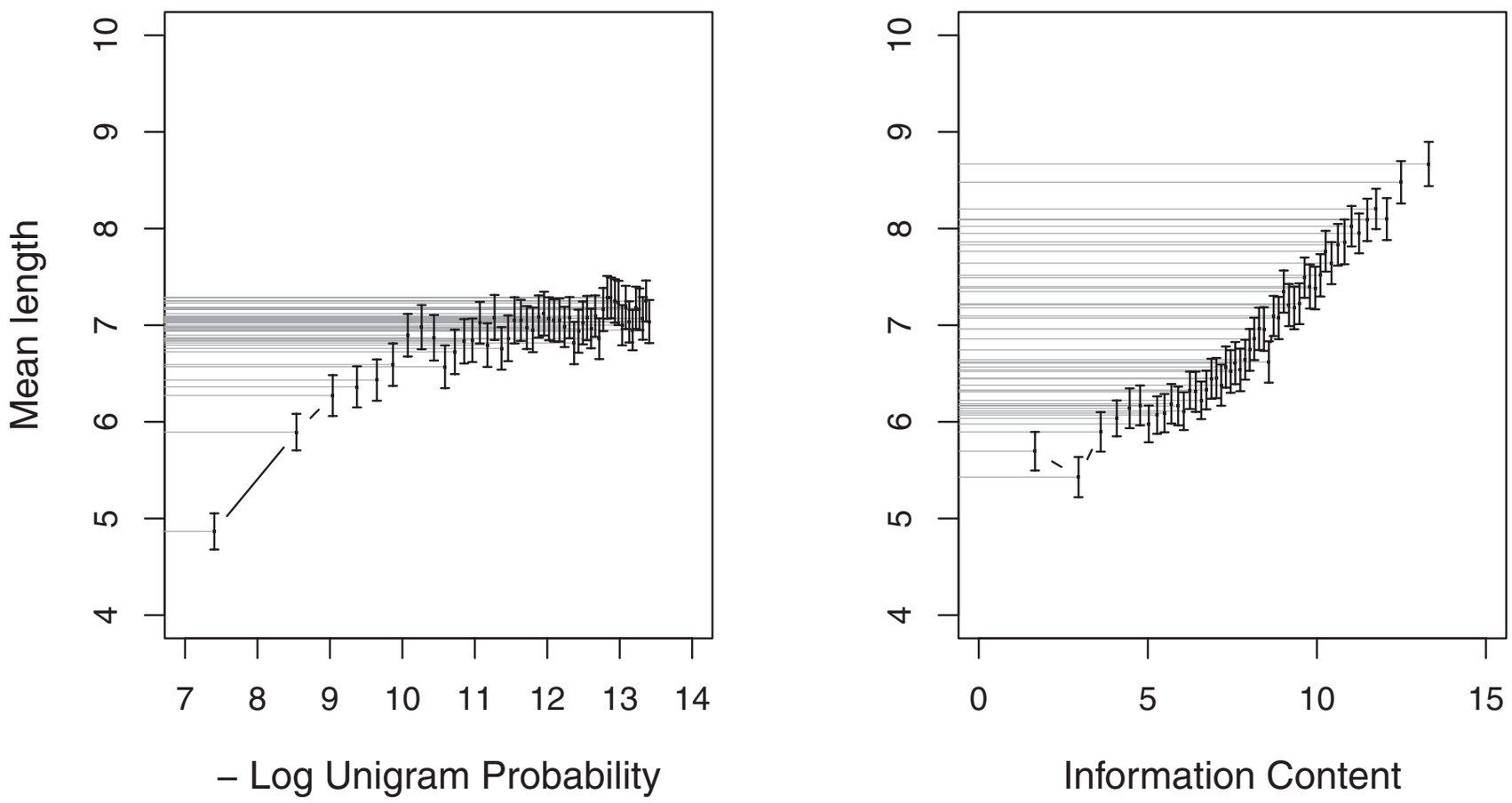
How could we tell?

- We could try to measure communicative accuracy in the same way we did in the models

- We could look at language from a design perspective: does it appear to be well-designed for communication?

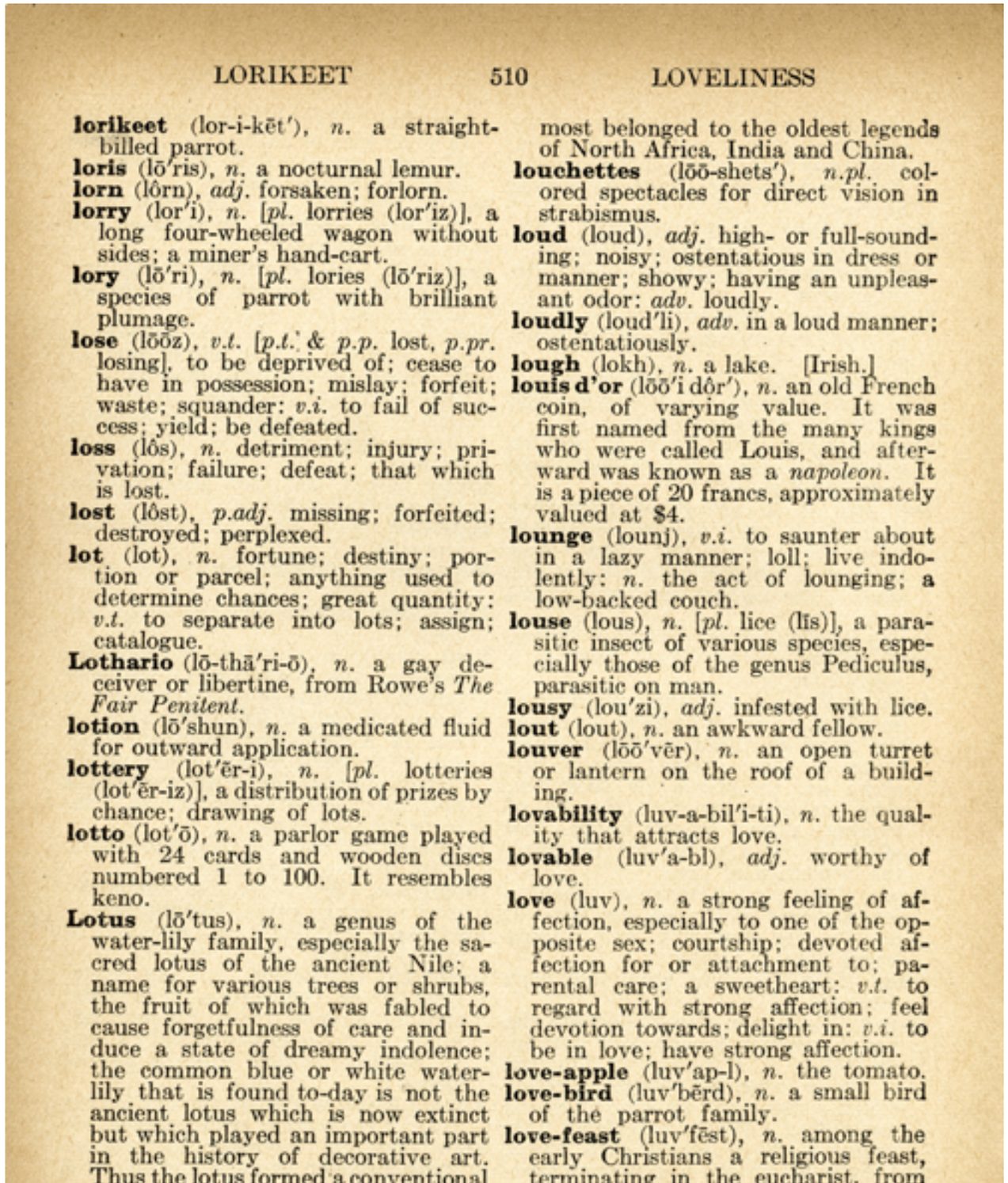
Are **the lexicons** of human language well-designed for communication?

- Zipf (1936): frequent words tend to be short
- Piantadosi, Tily & Gibson (2011): **predictable** words tend to be short



Are **the lexicons** of human language well-designed for communication?

- But ambiguity (homonymy and polysemy) are rampant - that must be bad, right?



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loris (lō′ris), *n.* a nocturnal lemur.
lorn (lôrn), *adj.* forsaken; forlorn.
lorry (lor′i), *n.* [*pl.* lorries (lor′iz)], a long four-wheeled wagon without sides; a miner's hand-cart.
lory (lō′ri), *n.* [*pl.* lories (lō′riz)], a species of parrot with brilliant plumage.
lose (lōōz), *v.t.* [*p.t.* & *p.p.* lost, *p.pr.* losing], to be deprived of; cease to have in possession; mislay; forfeit; waste; squander: *v.i.* to fail of success; yield; be defeated.
loss (lôs), *n.* detriment; injury; privation; failure; defeat; that which is lost.
lost (lôst), *p.adj.* missing; forfeited; destroyed; perplexed.
lot (lot), *n.* fortune; destiny; portion or parcel; anything used to determine chances; great quantity: *v.t.* to separate into lots; assign; catalogue.
Lothario (lō-thā′ri-ō), *n.* a gay deceiver or libertine, from Rowe's *The Fair Penitent.*
lotion (lō′shun), *n.* a medicated fluid for outward application.
lottery (lot′ẽr-i), *n.* [*pl.* lotteries (lot′ẽr-iz)], a distribution of prizes by chance; drawing of lots.
lotto (lot′ō), *n.* a parlor game played with 24 cards and wooden discs numbered 1 to 100. It resembles keno.
Lotus (lō′tus), *n.* a genus of the water-lily family, especially the sacred lotus of the ancient Nile; a name for various trees or shrubs, the fruit of which was fabled to cause forgetfulness of care and induce a state of dreamy indolence; the common blue or white water-lily that is found to-day is not the ancient lotus which is now extinct but which played an important part in the history of decorative art. Thus the lotus formed a conventional most belonged to the oldest legends of North Africa, India and China.
louchettes (lōō-shets′), *n.pl.* colored spectacles for direct vision in strabismus.
loud (loud), *adj.* high- or full-sounding; noisy; ostentatious in dress or manner; showy; having an unpleasant odor: *adv.* loudly.
loudly (loud′li), *adv.* in a loud manner; ostentatiously.
lough (lokh), *n.* a lake. [Irish.]
louis d'or (lōō′i dôr′), *n.* an old French coin, of varying value. It was first named from the many kings who were called Louis, and afterward was known as a *napoleon.* It is a piece of 20 francs, approximately valued at $4.
lounge (lounj), *v.i.* to saunter about in a lazy manner; loll; live indolently: *n.* the act of lounging; a low-backed couch.
louse (lous), *n.* [*pl.* lice (līs)], a parasitic insect of various species, especially those of the genus Pediculus, parasitic on man.
lousy (lou′zi), *adj.* infested with lice.
lout (lout), *n.* an awkward fellow.
louver (lōō′vẽr), *n.* an open turret or lantern on the roof of a building.
lovability (luv-a-bil′i-ti), *n.* the quality that attracts love.
lovable (luv′a-bl), *adj.* worthy of love.
love (luv), *n.* a strong feeling of affection, especially to one of the opposite sex; courtship; devoted affection for or attachment to; parental care; a sweetheart; *v.t.* to regard with strong affection; feel devotion towards; delight in: *v.i.* to be in love; have strong affection.
love-apple (luv′ap-l), *n.* the tomato.
love-bird (luv′bẽrd), *n.* a small bird of the parrot family.
love-feast (luv′fēst), *n.* among the early Christians a religious feast, terminating in the eucharist, from

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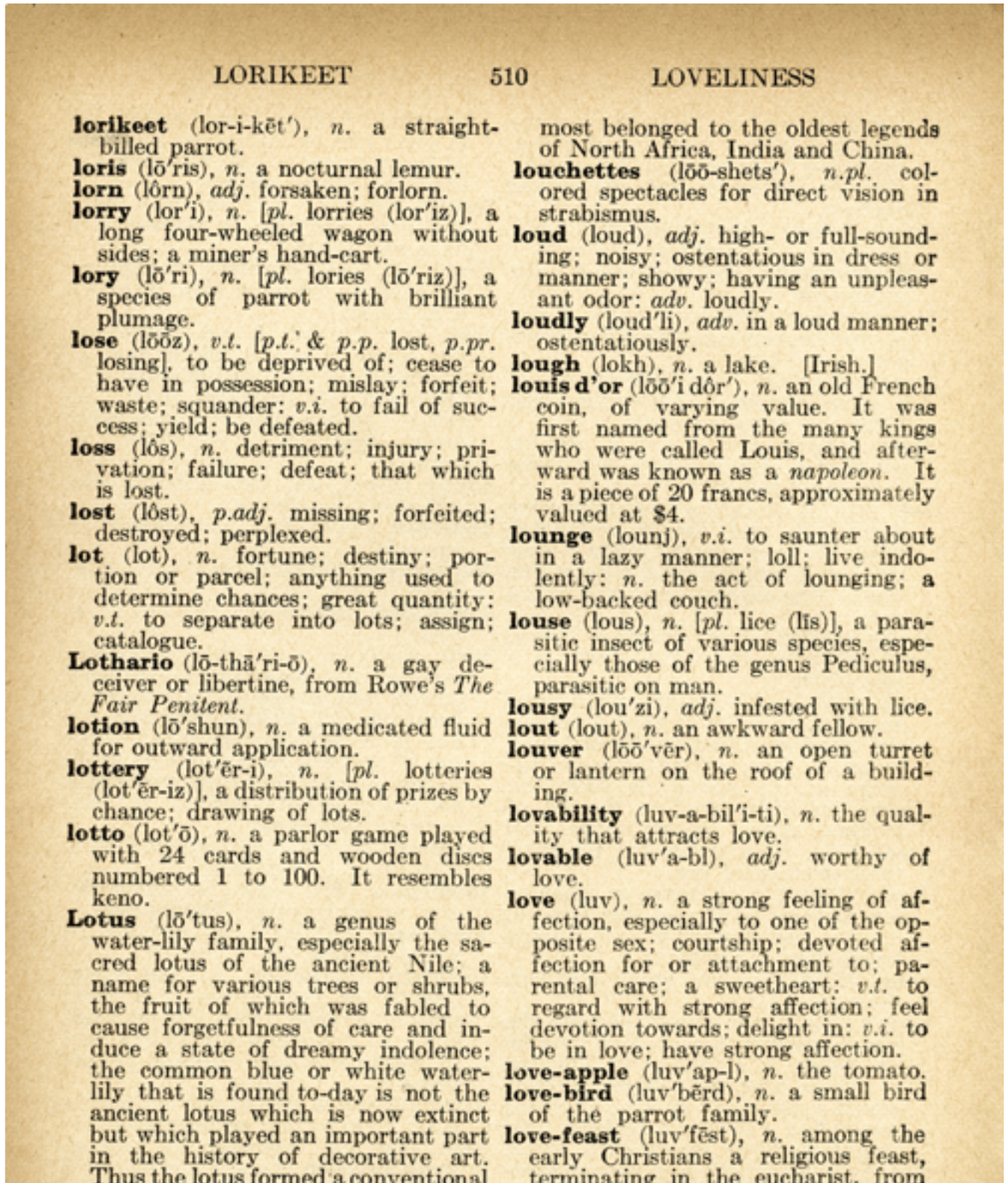
- But ambiguity (homonymy and polysemy) are rampant - that must be bad, right?

- “If you want to make sure that we never misunderstand one another, for that purpose language is not well designed, because you have such properties as ambiguity. If we want to have the property that the things that we usually would like to say come out short and simple, well, it probably doesn’t have that property.” (Chomsky, 2002, p. 107)



LORIKEET 510 LOVELINESS

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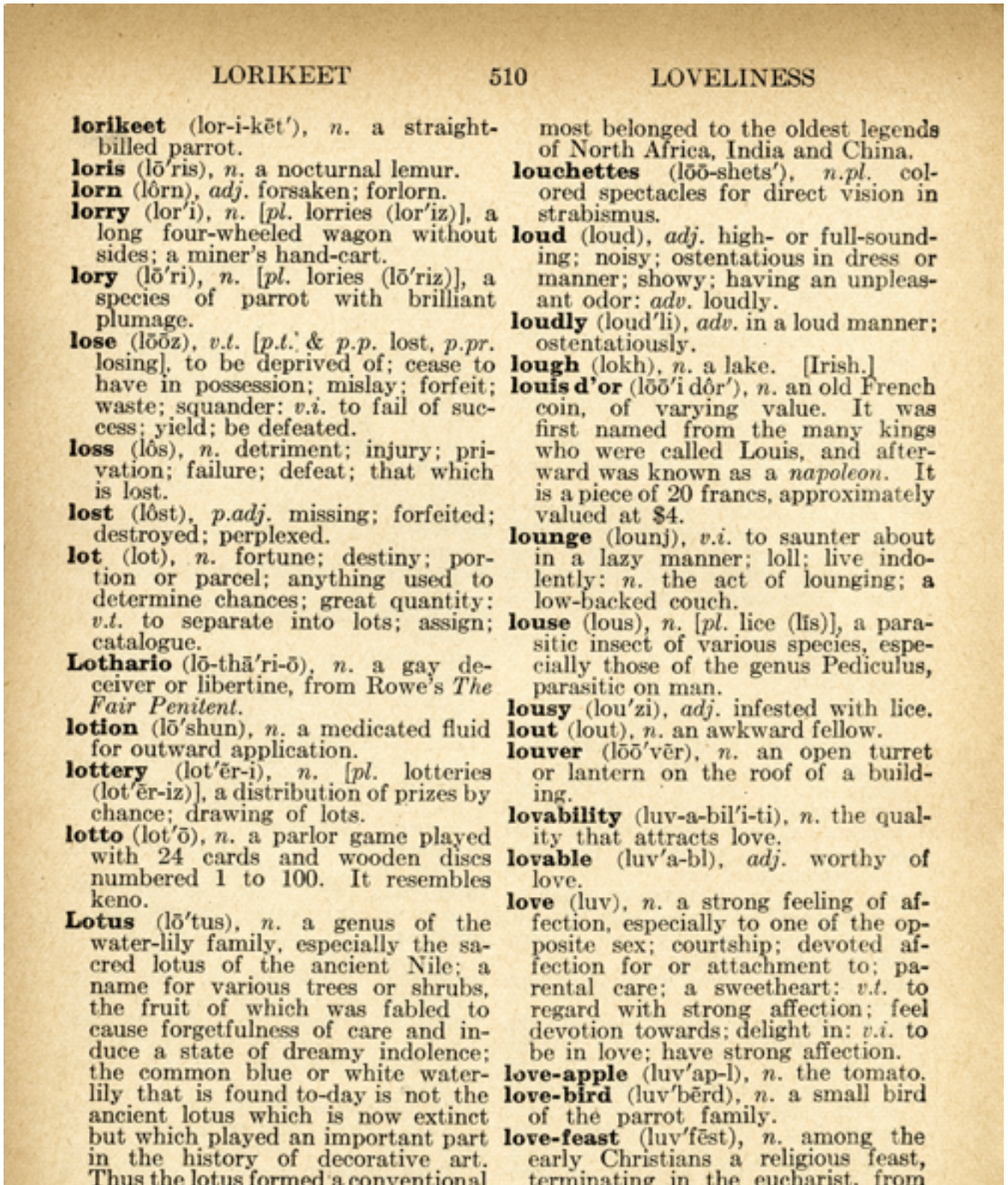
Are **the lexicons** of human language well-designed for communication?

- But ambiguity (homonymy and polysemy) are rampant - that must be bad, right?

- “If you want to make sure that we never misunderstand one another, for that purpose language is not well designed, because you have such properties as ambiguity. ~~If we want to have the property that the things that we usually would like to say come out short and simple, well, it probably doesn’t have that property.~~” (Chomsky, 2002, p. 107)



LORIKEET 510 LOVELINESS

lorikeet (lor-i-kēt′), *n.* a straight-billed parrot.
loris (lō′ris), *n.* a nocturnal lemur.
lorn (lôrn), *adj.* forsaken; forlorn.
lorry (lor′i), *n.* [*pl.* lorries (lor′iz)], a long four-wheeled wagon without sides; a miner's hand-cart.
lory (lō′ri), *n.* [*pl.* lories (lō′riz)], a species of parrot with brilliant plumage.
lose (lōōz), *v.t.* [*p.t.* & *p.p.* lost, *p.pr.* losing], to be deprived of; cease to have in possession; mislay; forfeit; waste; squander: *v.i.* to fail of success; yield; be defeated.
loss (lôs), *n.* detriment; injury; privation; failure; defeat; that which is lost.
lost (lôst), *p.adj.* missing; forfeited; destroyed; perplexed.
lot (lot), *n.* fortune; destiny; portion or parcel; anything used to determine chances; great quantity: *v.t.* to separate into lots; assign; catalogue.
Lothario (lō-thā′ri-ō), *n.* a gay deceiver or libertine, from Rowe's *The Fair Penitent.*
lotion (lō′shun), *n.* a medicated fluid for outward application.
lottery (lot′ẽr-i), *n.* [*pl.* lotteries (lot′ẽr-iz)], a distribution of prizes by chance; drawing of lots.
lotto (lot′ō), *n.* a parlor game played with 24 cards and wooden discs numbered 1 to 100. It resembles keno.
Lotus (lō′tus), *n.* a genus of the water-lily family, especially the sacred lotus of the ancient Nile; a name for various trees or shrubs, the fruit of which was fabled to cause forgetfulness of care and induce a state of dreamy indolence; the common blue or white water-lily that is found to-day is not the ancient lotus which is now extinct but which played an important part in the history of decorative art. Thus the lotus formed a conventional most belonged to the oldest legends of North Africa, India and China.
louchettes (lōō-shets′), *n.pl.* colored spectacles for direct vision in strabismus.
loud (loud), *adj.* high- or full-sounding; noisy; ostentatious in dress or manner; showy; having an unpleasant odor: *adv.* loudly.
loudly (loud′li), *adv.* in a loud manner; ostentatiously.
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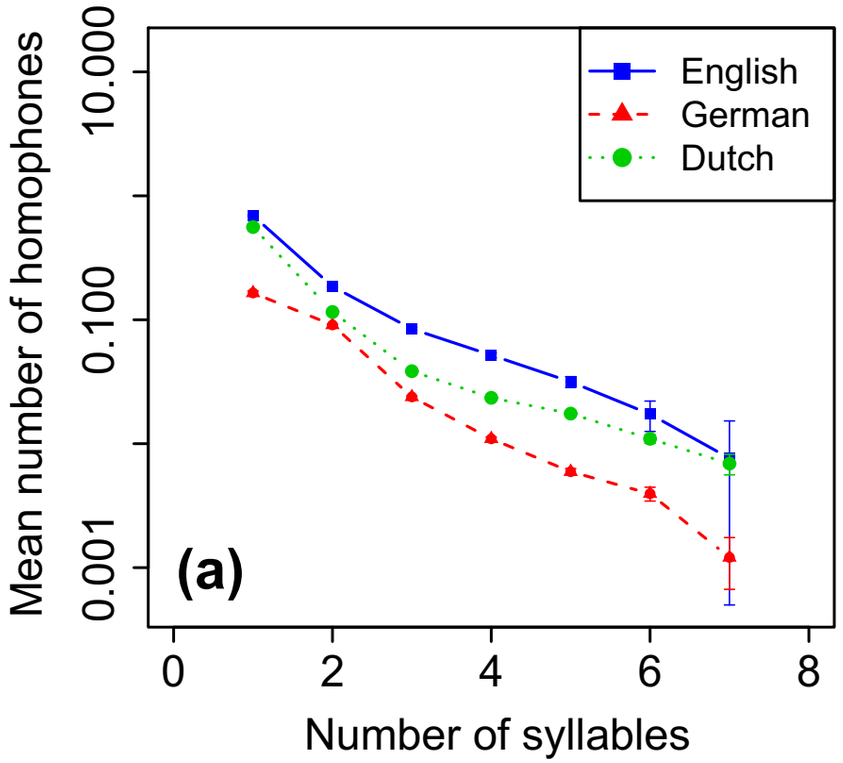
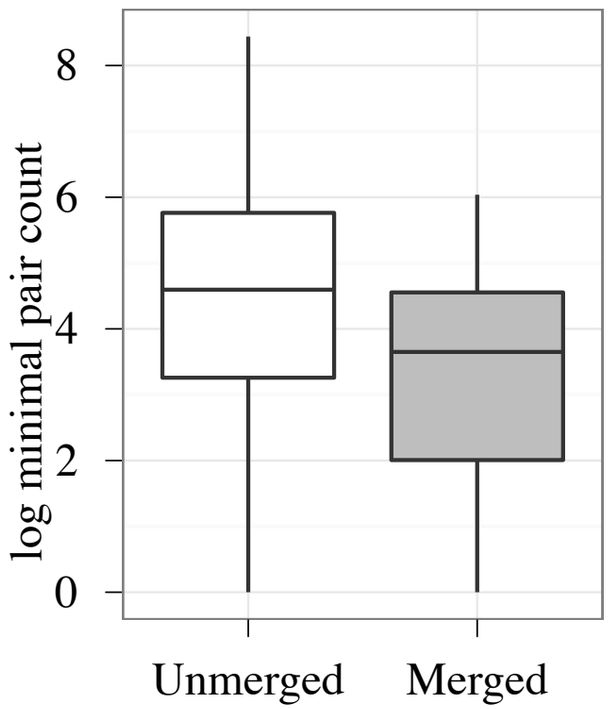
- Maybe ambiguity isn't always bad?
  - There aren't that many short words, and being short is good
  - Having fewer words to learn / select among makes life easier



From Piantadosi, Tily & Gibson (2012)



From Wedel, Kaplan & Jackson (2013)

Are **the lexicons** of human language well-designed for communication?

- Maybe ambiguity isn't always bad?
  - There aren't that many short words, and being short is good
  - Having fewer words to learn / select among makes life easier
- And anyway, how often is an ambiguous word actually ambiguous?
  - Context matters (and is lacking from our signalling models)

A co-evolutionary hypothesis (Smith 2004)

Children's learning biases have evolved through natural selection, because they're good for communication.

- Examine this idea using our model
- Two central assumptions:
  - Weight update rule is given by a genotype
  - Better communicators breed more

Invasion of the mutants

- Smith (2004) plays **constructors**, **maintainers**, and **learners** off against each other

- Create a population mainly made up of one type, but with a small number of another type (the mutant)

- Agents inherit both the communication system (by cultural transmission), and their learning strategy (by genetic transmission)

- Both culture and biology evolve

- If selection is based on communicative success, which mutants will invade?

Surprising result: evolution is hard

- Constructors don't often invade, *even though it would increase the fitness of the population if they did*

- Two problems:
  - Need a lot of mutants before they start to have a good effect on the population's language...
  - ...and even then, there's a time-delay before the good language evolves culturally.

- Speculative conclusion: human learning biases *haven't* evolved only for communication.

Summary

- Smith (2002, 2004) look in detail at how learning bias can give us (or fail to give us) language

- Brings together 3 complex processes in one model:

  Learning
  Cultural transmission
  Biological evolution

- Highlights the crucial importance of the second of these three

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