The Cultural Evolution of Language: can we study it in the lab?

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Why is language the way it is?

The evolutionary approach

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UNIVERSAL PROPERTIES
OF LINGUISTIC
STRUCTURE

Why is language the way it is?
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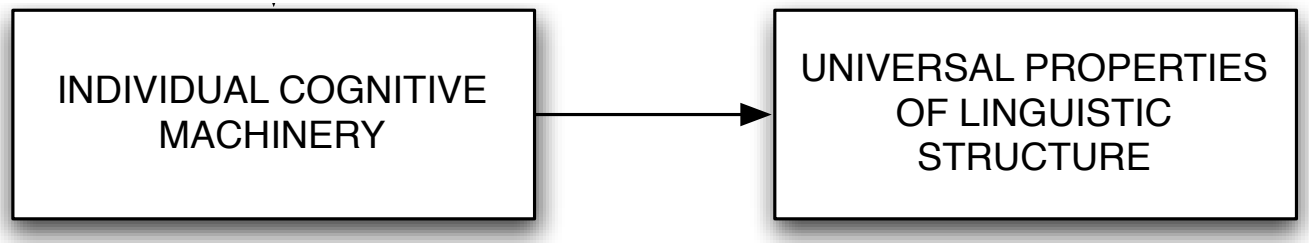
The 'orthodox' view



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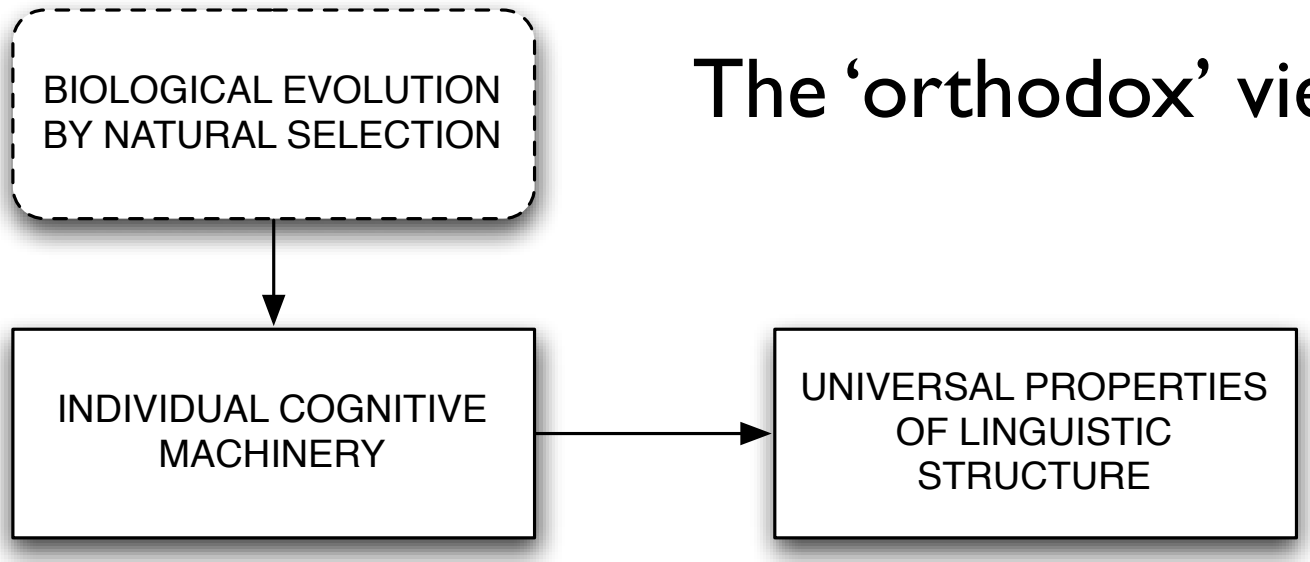

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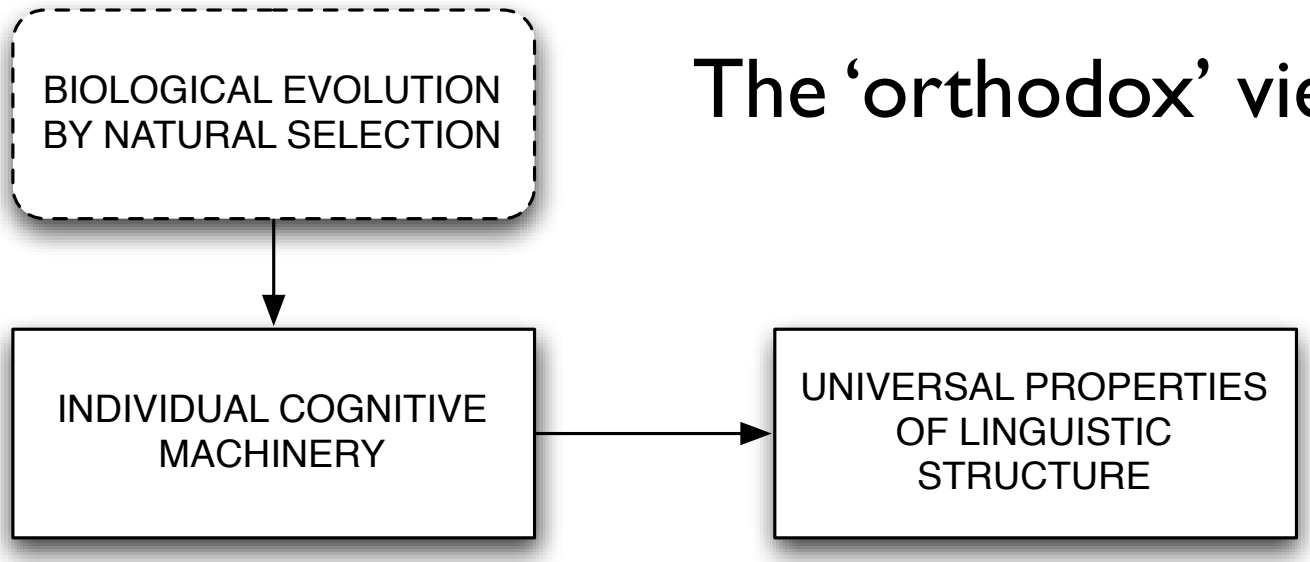

The 'orthodox' view

- The origins of language lie in the origins of language-specific innate biases/constraints whose function is to support communication

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- The Problem of Linkage
  - Language does not straightforwardly emerge from the idealised individual speaker/hearer

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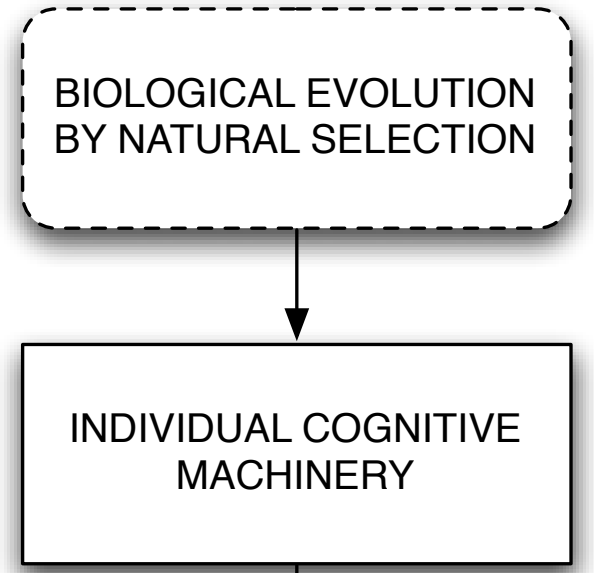
The evolutionary approach

- The Problem of Linkage
  - Language does not straightforwardly emerge from the idealised individual speaker/hearer
- It is the result of a socio/cultural process
  - Language structure emerges from the interaction of individuals (albeit ones with particular biases)

Why is language the way it is?
The evolutionary approach



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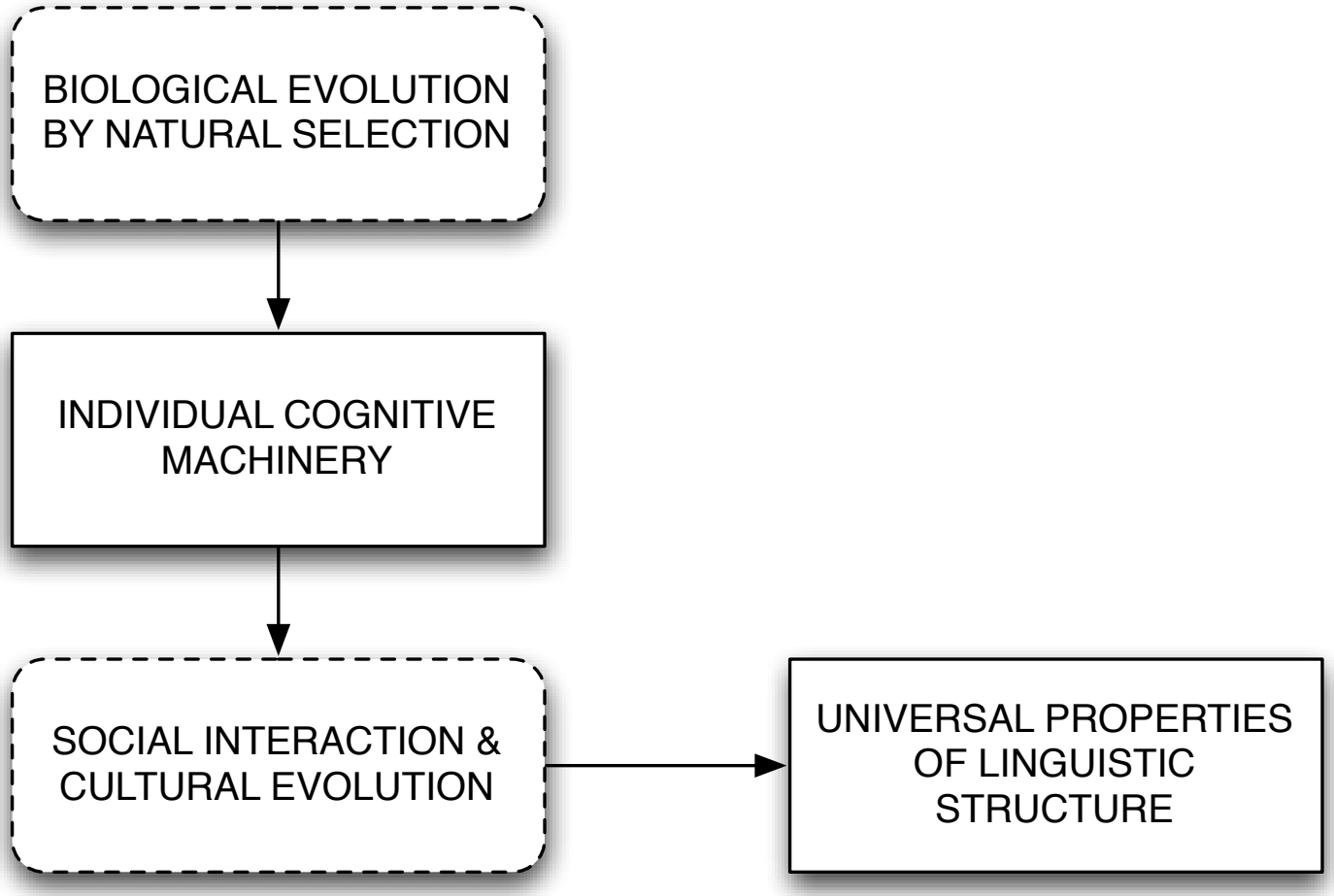

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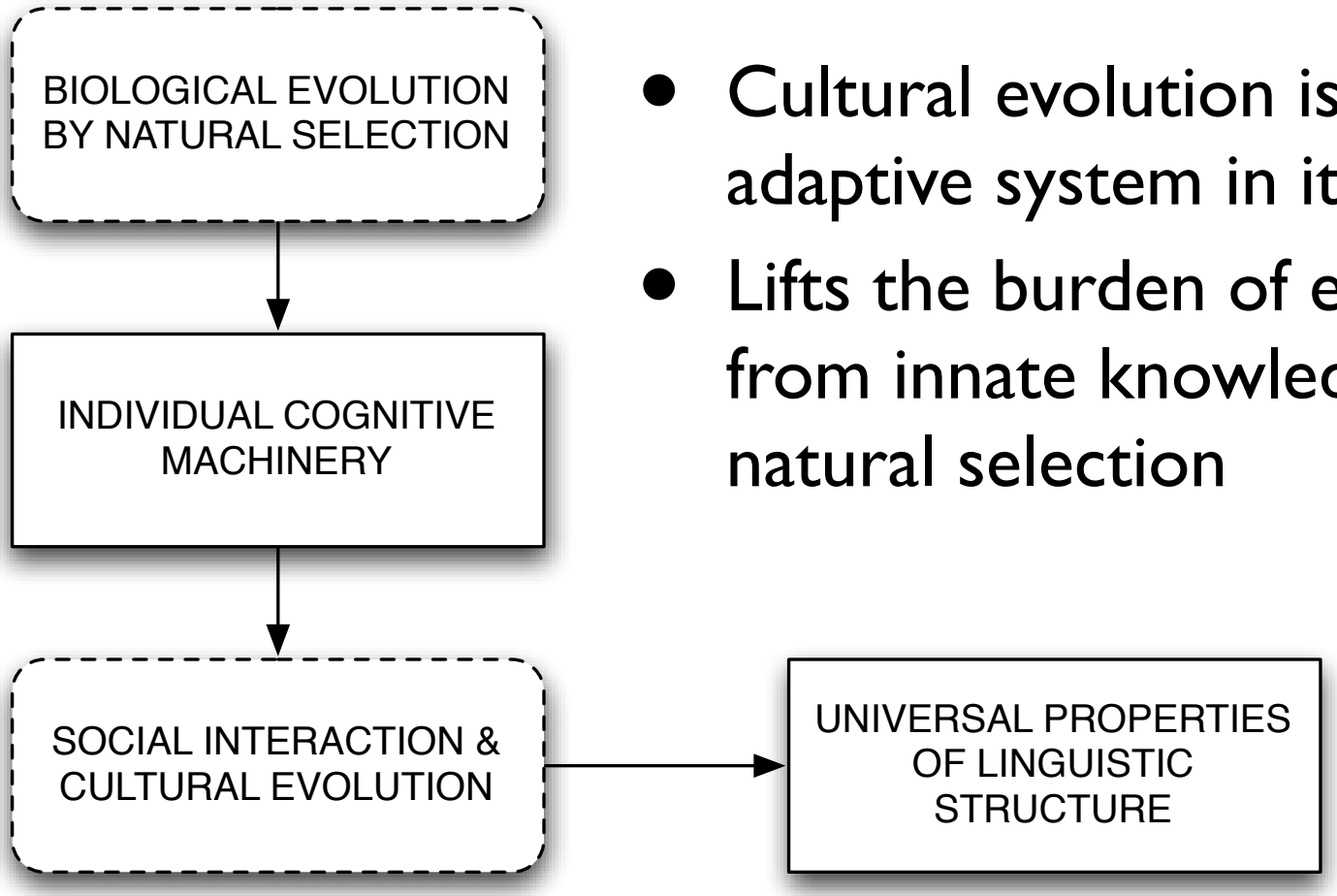
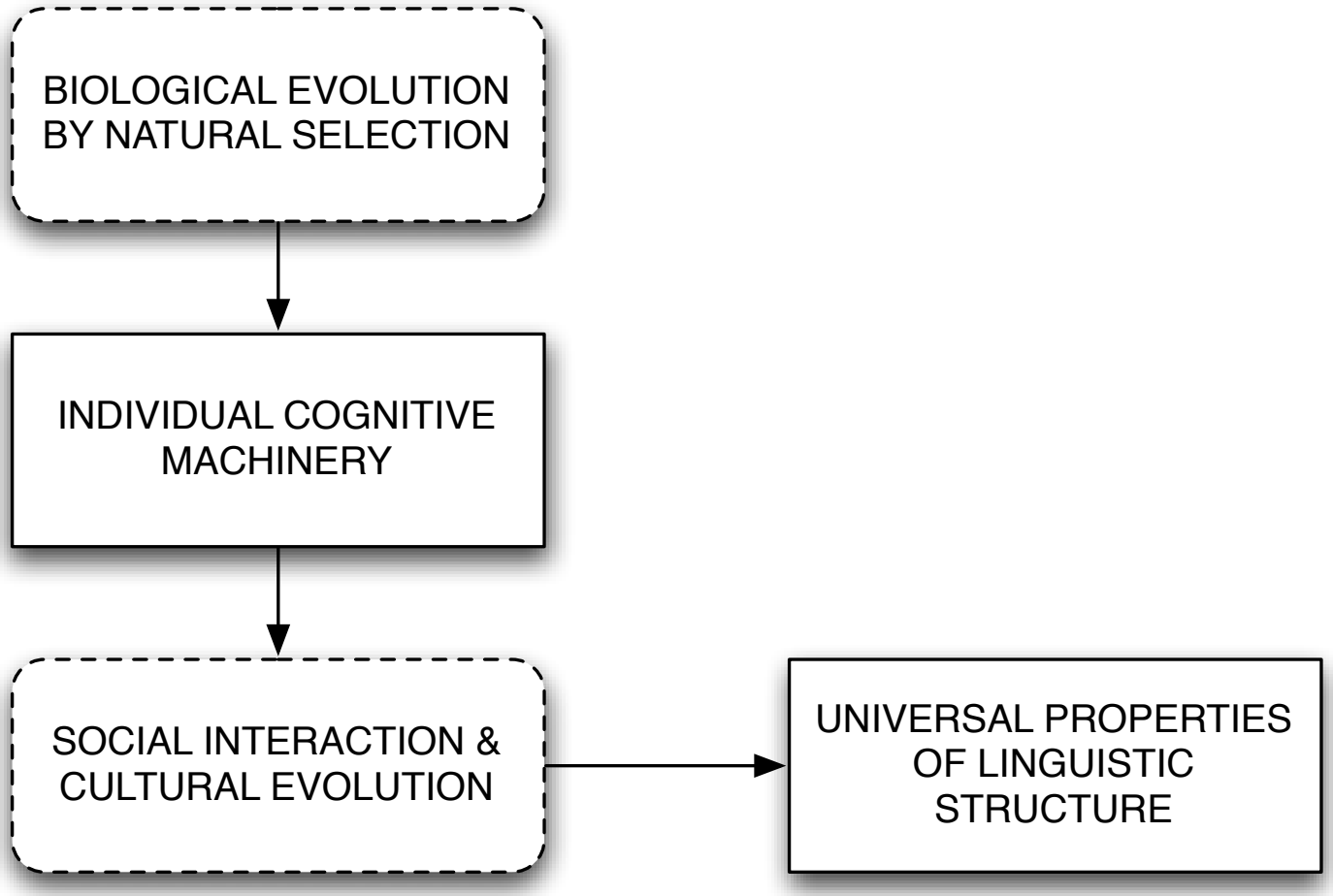


- Cultural evolution is an adaptive system in its own right
- Lifts the burden of explanation from innate knowledge *and* natural selection

OK... how do we study this?



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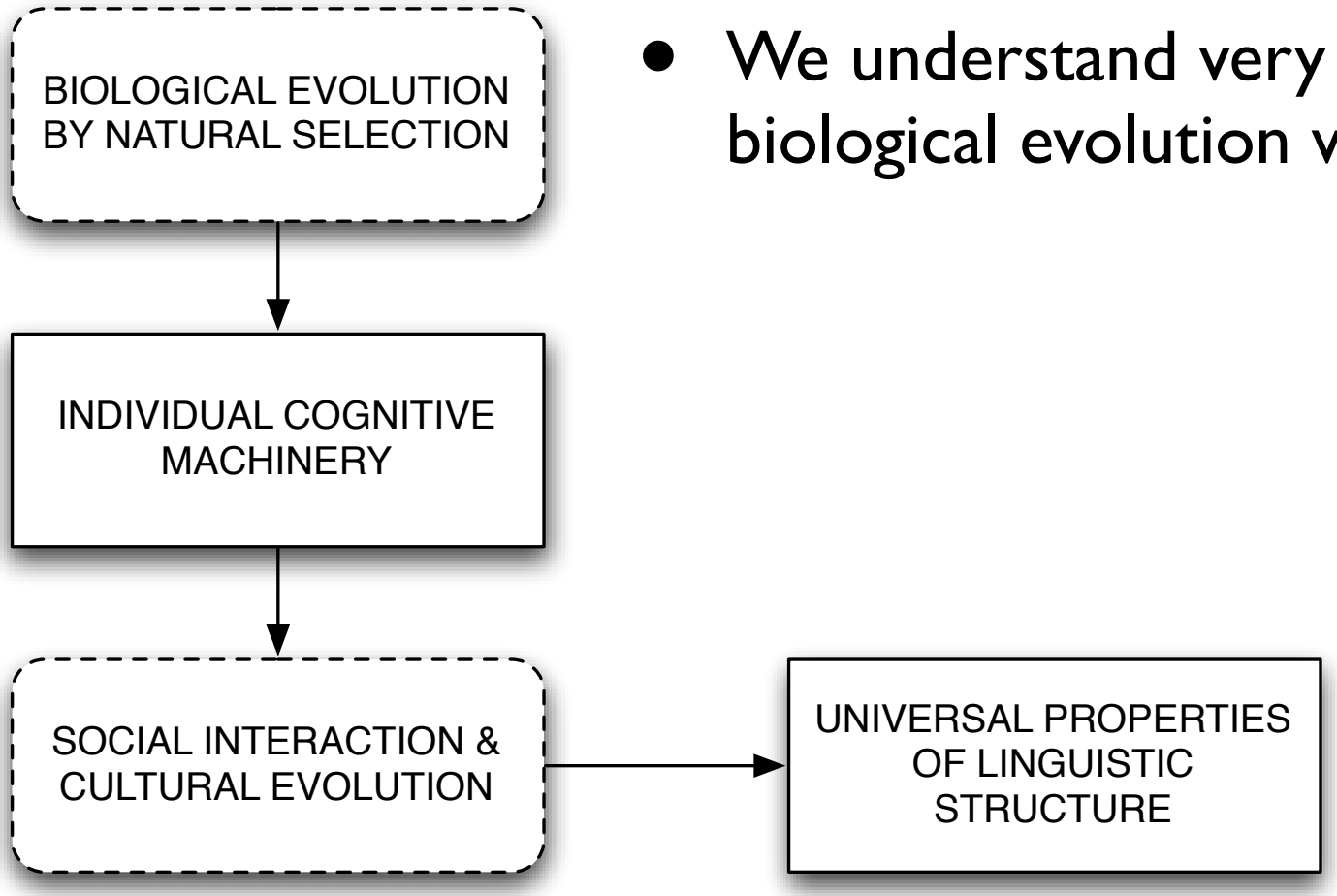

- We understand very well how biological evolution works

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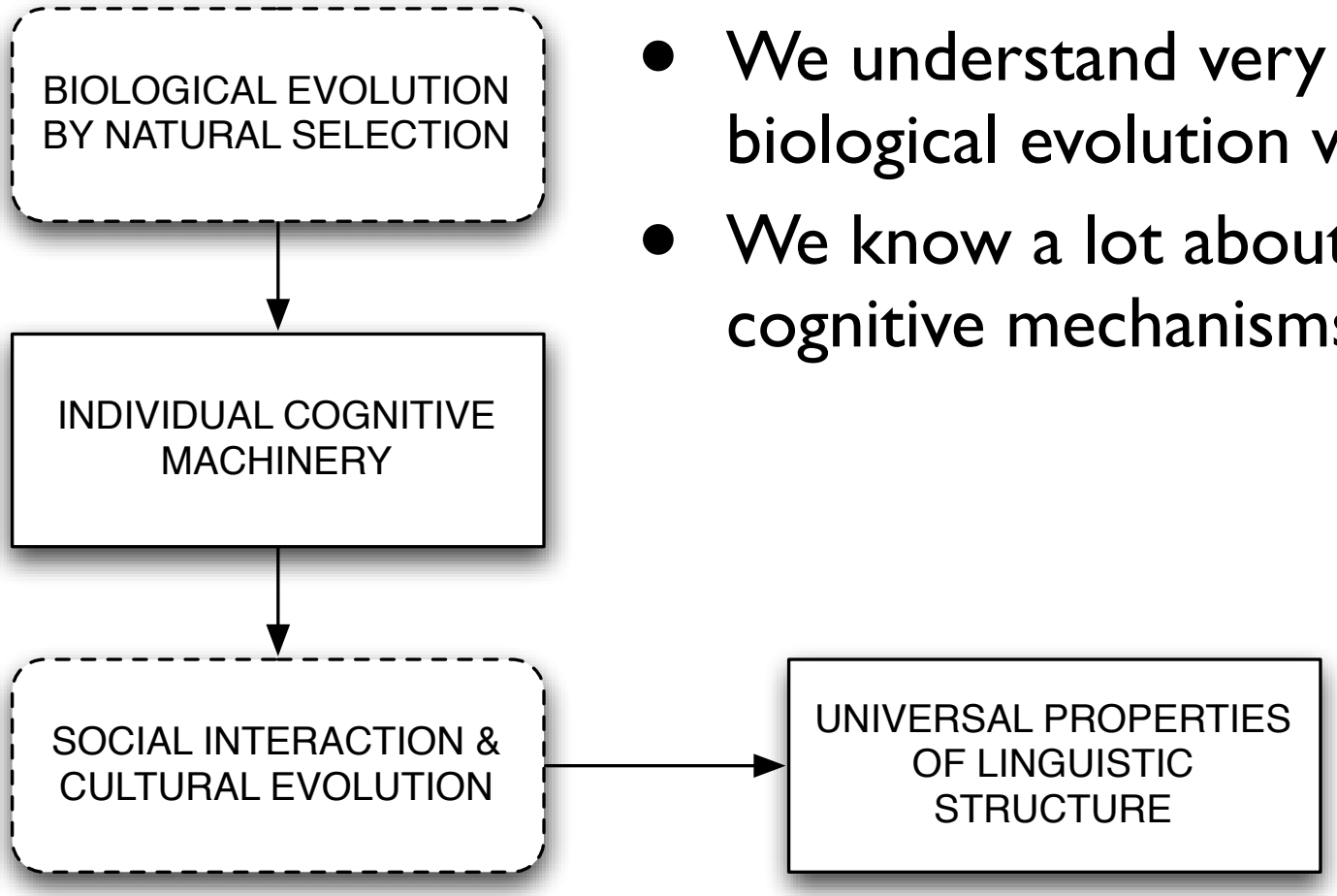

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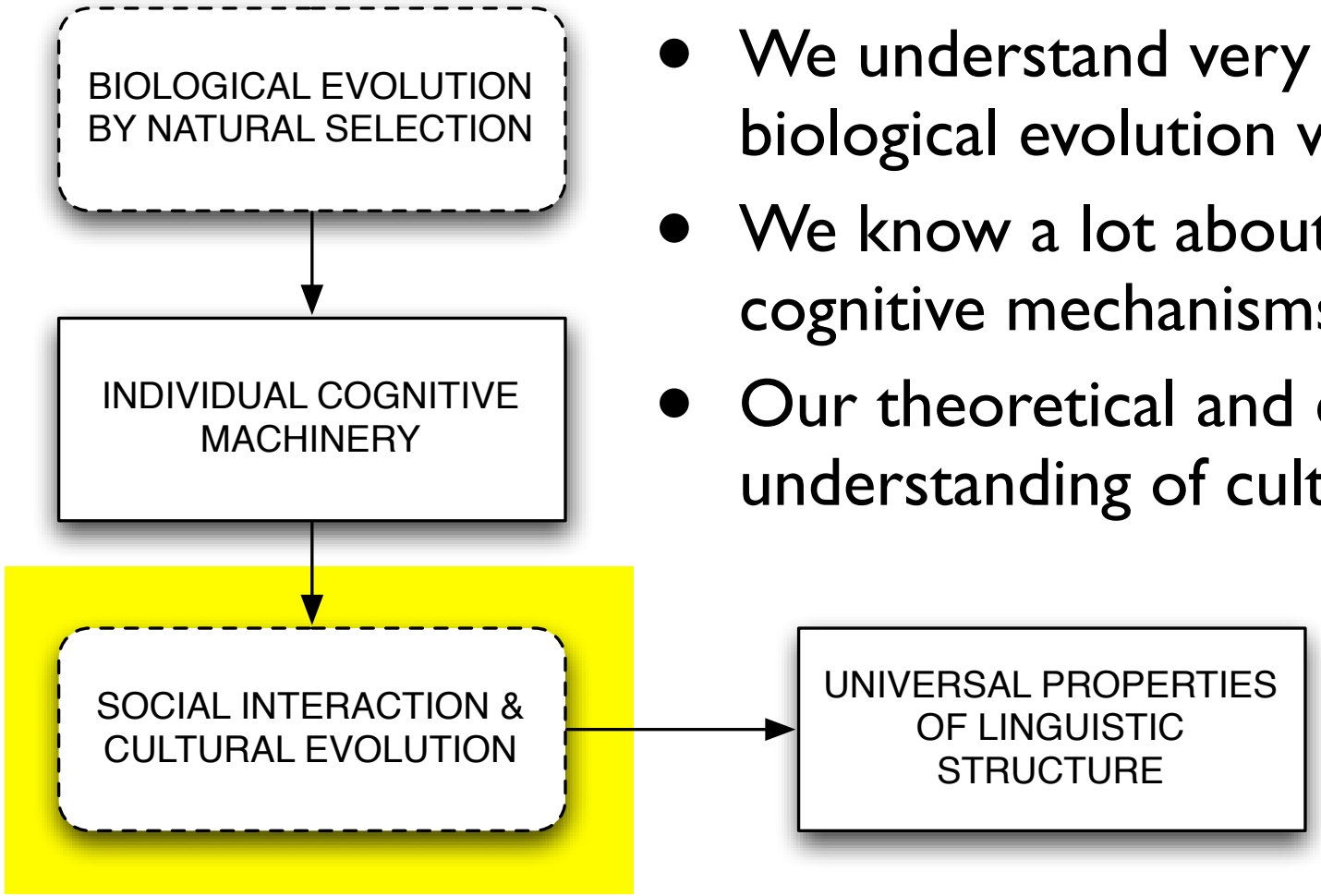

- We understand very well how biological evolution works
- We know a lot about individual cognitive mechanisms
- Our theoretical and empirical understanding of culture is poor

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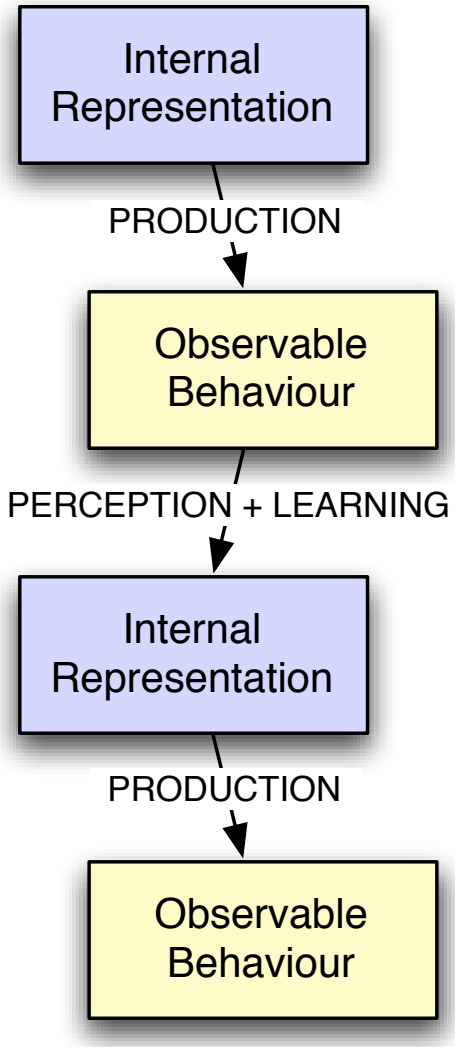
- Possible approaches:
  - Look at processes in naturalistic settings, e.g. in emerging languages
  - Build computational and mathematical models of cultural evolution
  - Try and find ways of replicating cultural process in laboratory conditions

Previous modelling work
(a whistle-stop tour)

- The Iterated Learning Model (mid 90s onwards)
  - Multi-agent modelling techniques applied to cultural evolution
  - Embed simple models of learners in a dynamic population and an "environment" about which they try to communicate
  - Agents learn to communicate by observing others, who themselves learned the same way (cf. "Chinese Whispers")



Previous modelling work
(a whistle-stop tour)

- Key insight: *transmission bottlenecks*
  - If a learner is given imperfect information about the language, e.g. noise, processing constraints, or simply not hearing all the data
  - ... cultural transmission becomes an adaptive system.
  - Language will adapt so that it appears to be designed to "fit" the bottleneck.

Previous modelling work
(a whistle-stop tour)

- Recent mathematical idealisation
  (Kirby, Dowman & Griffiths 2007, *PNAS*)
  - Confirms modelling results
  - Under reasonable assumptions about learning, strength of innate biases has no effect on strength of universal constraints
  - Cultural adaptation is the key process

Previous modelling work
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- To summarise:
  - Language structure does not necessarily reflect innate constraints
  - Adaptive structure in language does not imply natural selection (*contra* Pinker)

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- Can we be sure this would work in real human agents?

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- Models suggest that a culturally transmitted system will spontaneously adapt to aid its own survival
- Can we be sure this would work in real human agents?
- Can we show adaptation of a language through cultural transmission *without intentional design on the part of the learners of the language?*

An experimental approach

- Combine *diffusion chain* and *artificial language learning* studies

Cornish (2006, *MSc*); Kirby, Cornish & Smith (forthcoming)

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An experimental approach

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  1. Start off with a random artificial language
  2. Ask an experimental subject to try and learn this language and test them
  3. Use their output on test as the language to teach the next subject in the experiment (and repeat)

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Hypothesis

- There will be cumulative cultural adaptation of the language without intentional design by participants

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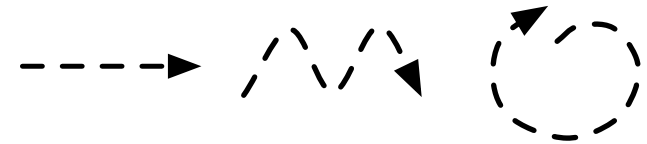
- Two ways of verifying this:
  - The language should become easier to learn
  - The language should become structured

The Language

The Language

- A set of 27 possible "meanings"
  - Pictures with coloured objects in motion:
    - Three shapes □ ○ △
    - Three colours 
    - Three motions 

The Language

- A set of 27 possible "meanings"
  - Pictures with coloured objects in motion:
    - Three shapes 
    - Three colours 
    - Three motions 
- A set of 7371 possible "signals"
  - Random sequences of between two and four syllables chosen from a set of nine
  - No spaces

Procedure

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- Language divided randomly into two sets:
  - SEEN set: 14 string-picture pairs
  - UNSEEN set: remaining 13 string-picture pairs

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- String displayed for 1 second, then string and picture for a further 5 seconds

kihemiwi

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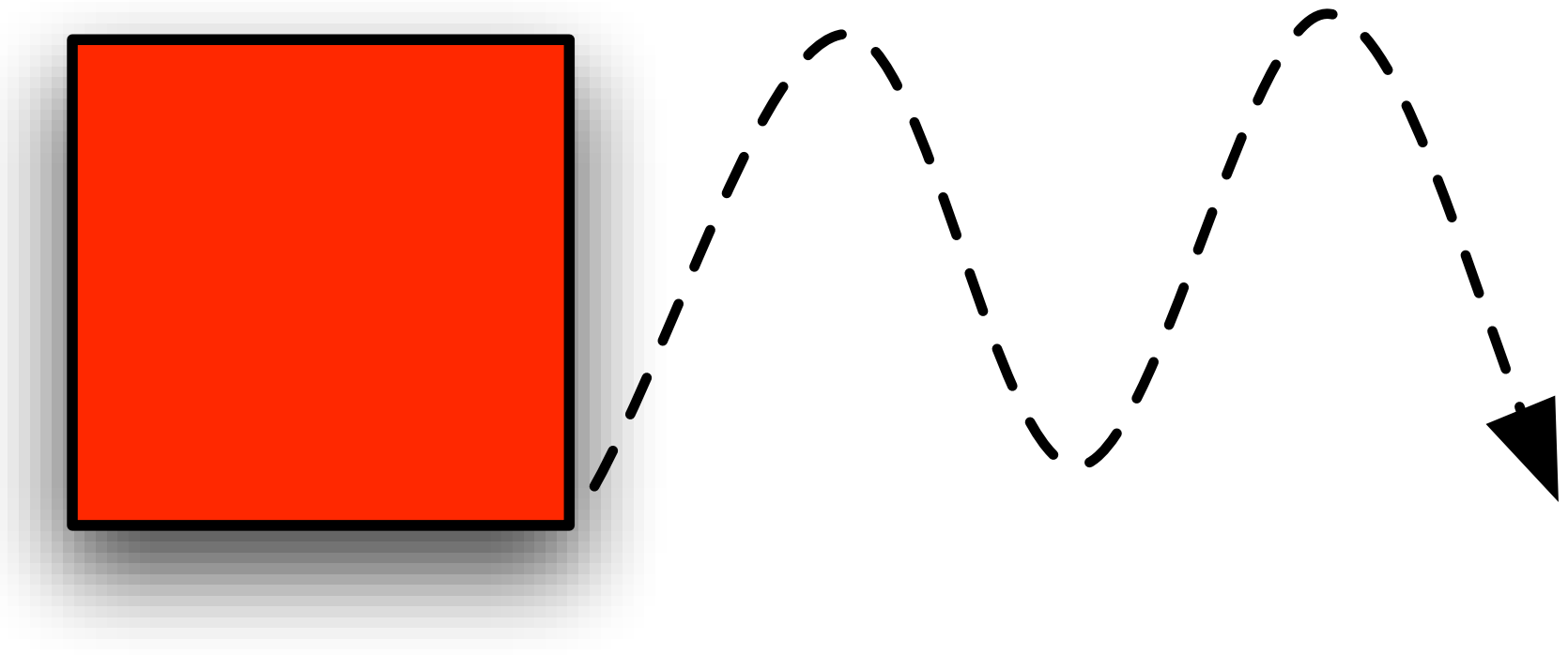
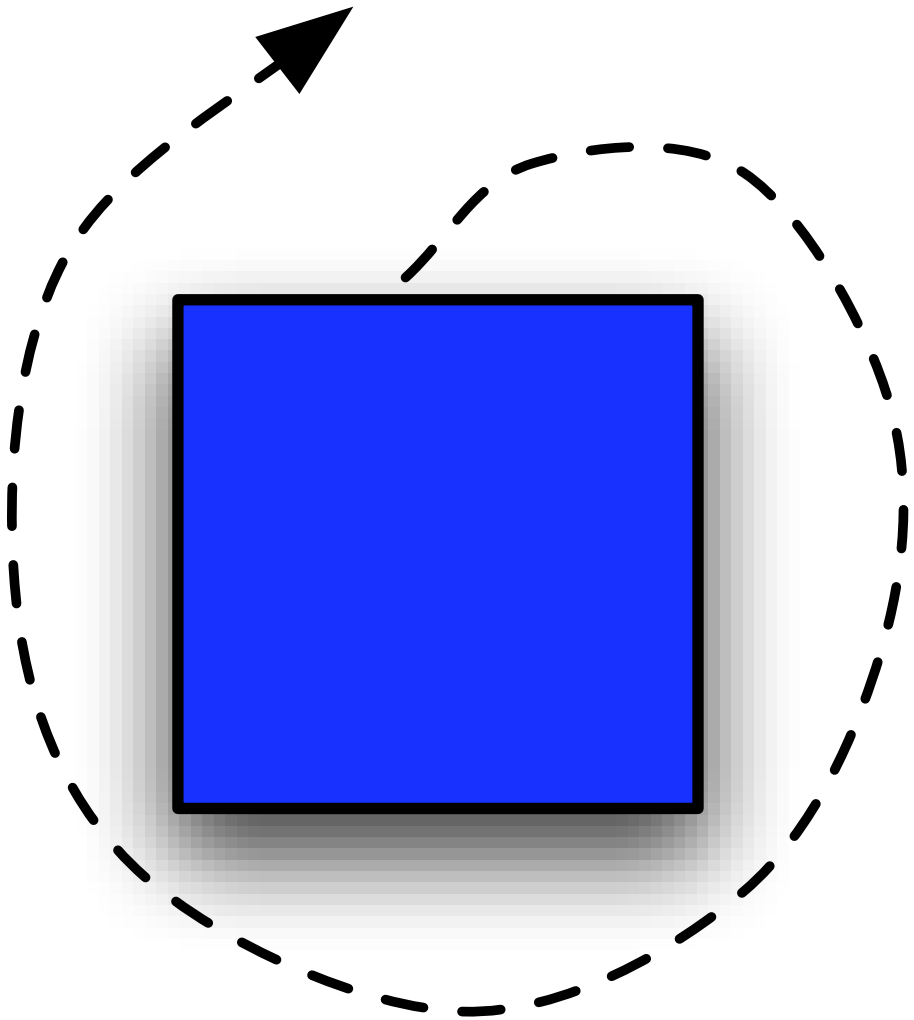


kunige

kunige



Training/testing schedule

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- **Train on SEEN x2**
- Test on half of SEEN and half of UNSEEN
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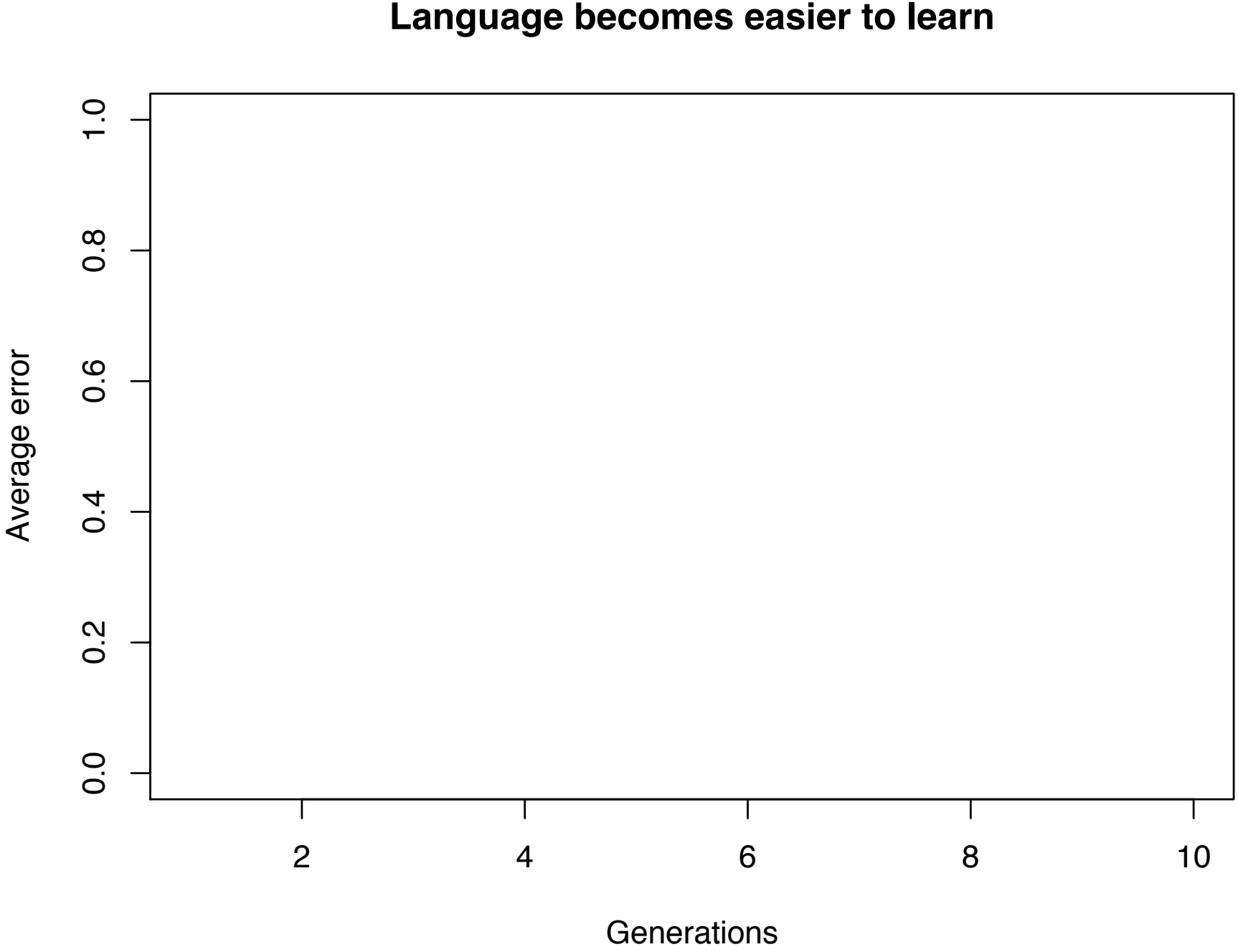
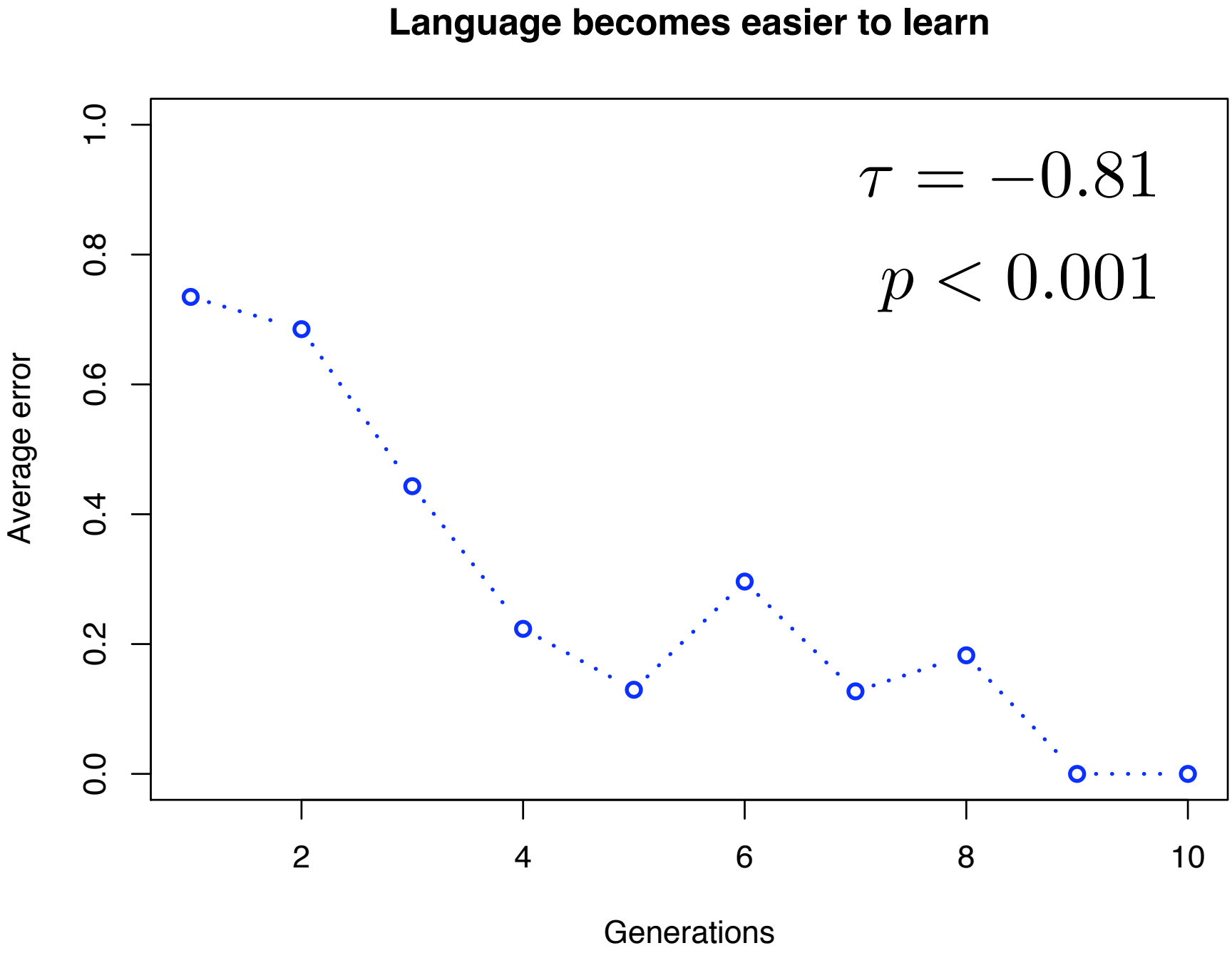
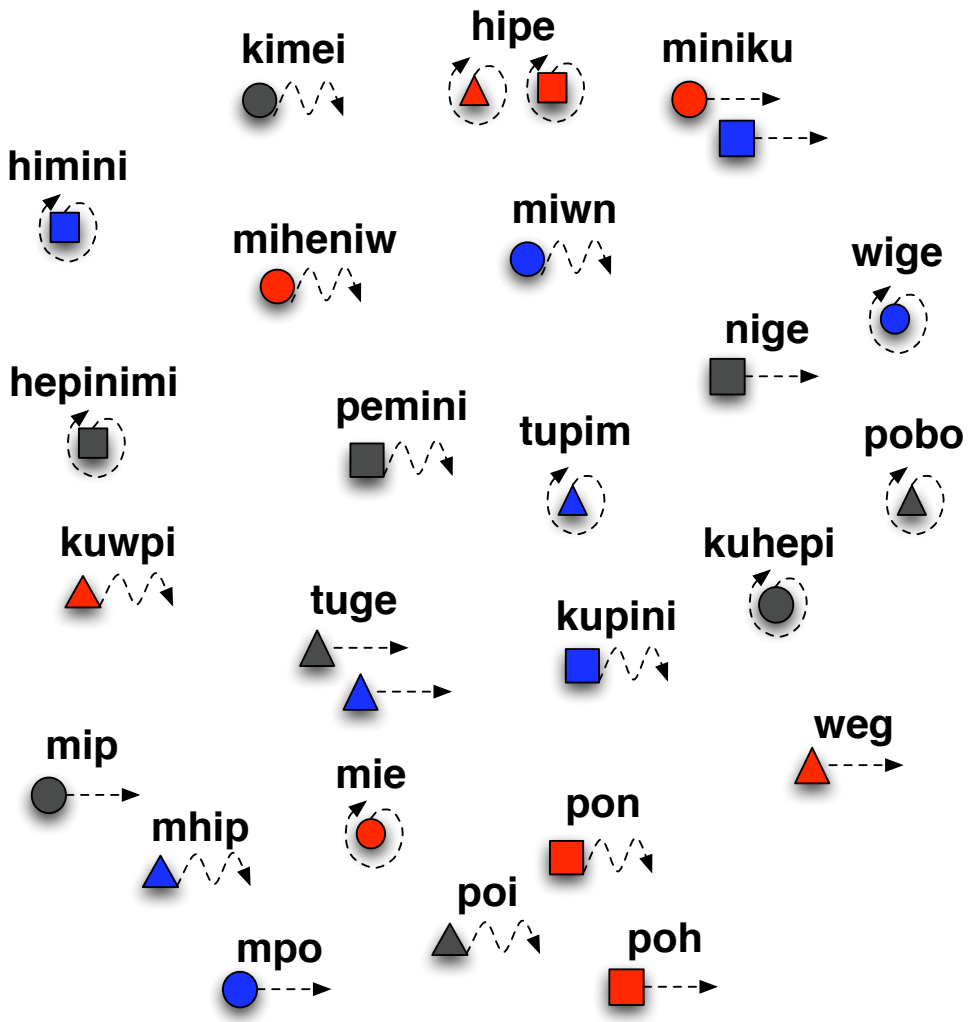
- Output of final test is divided into new SEEN and UNSEEN sets for next "generation"


Language becomes easier to learn
Average error
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Generations


Language becomes easier to learn
$\tau = -0.81$
$p < 0.001$
Average error
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Generations

After Generation 1:



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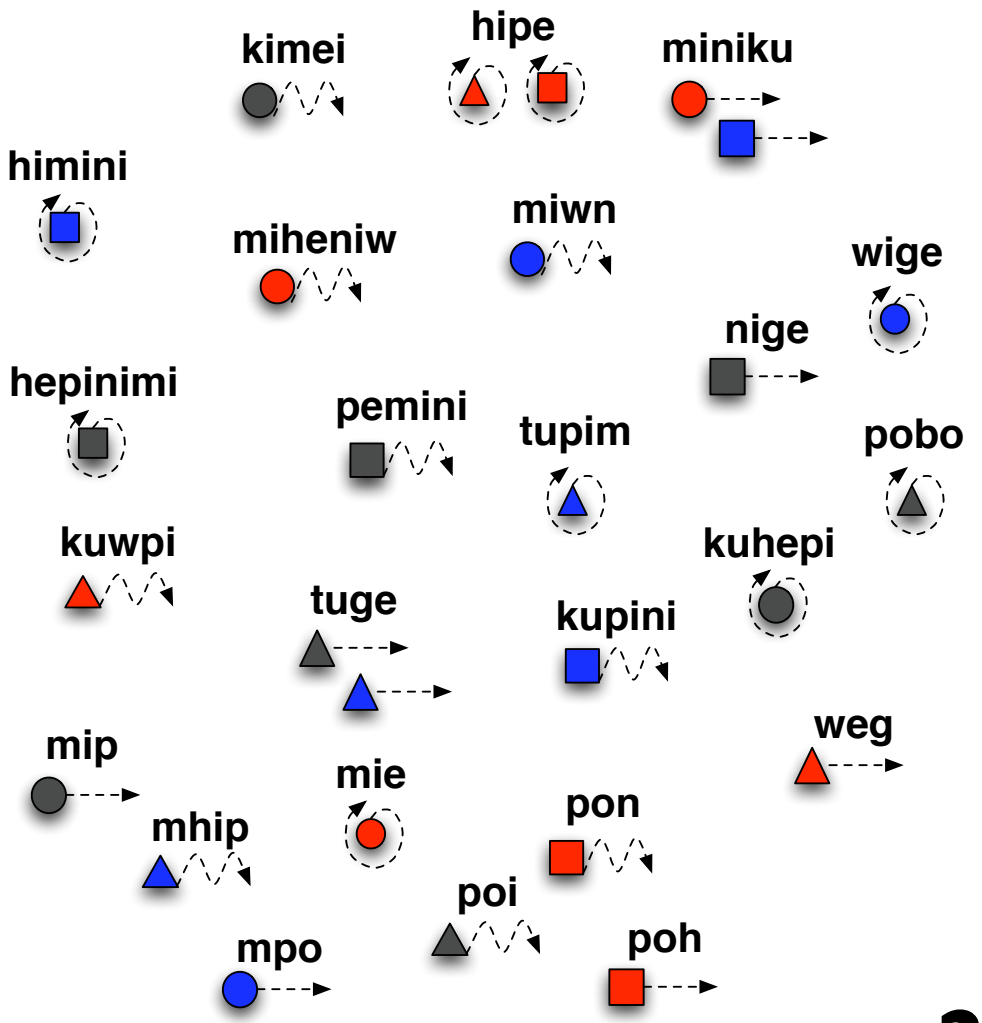
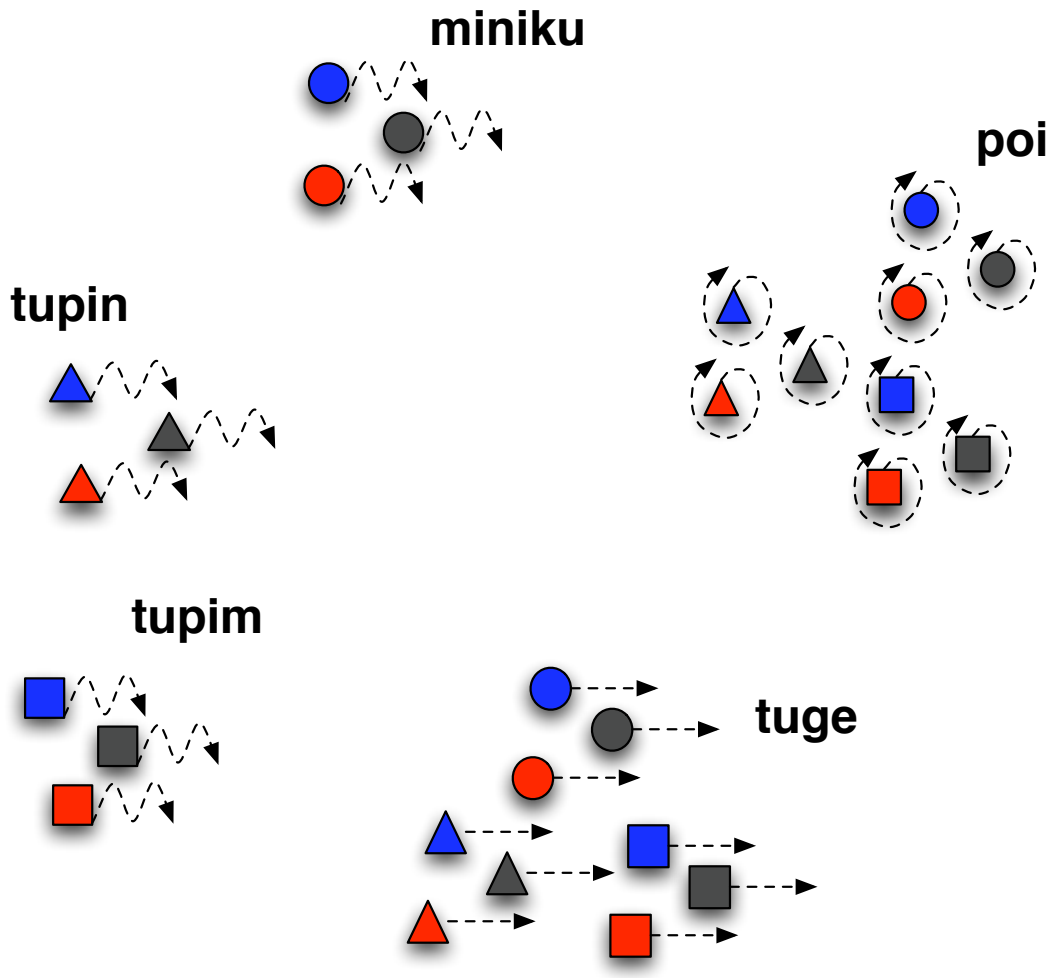
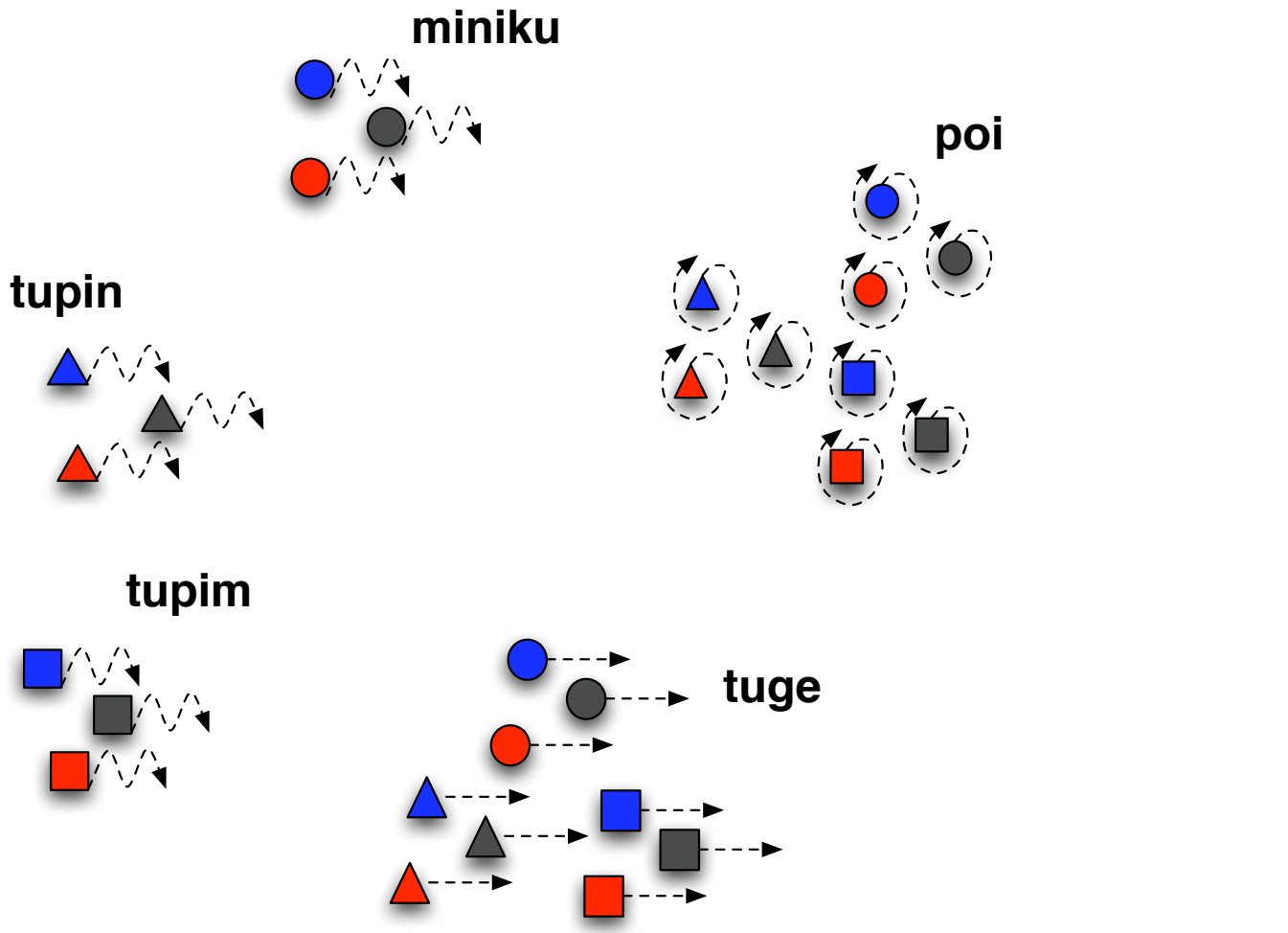


24 words

After Generation 10:



After Generation 10:



5 words

How has language become easier?

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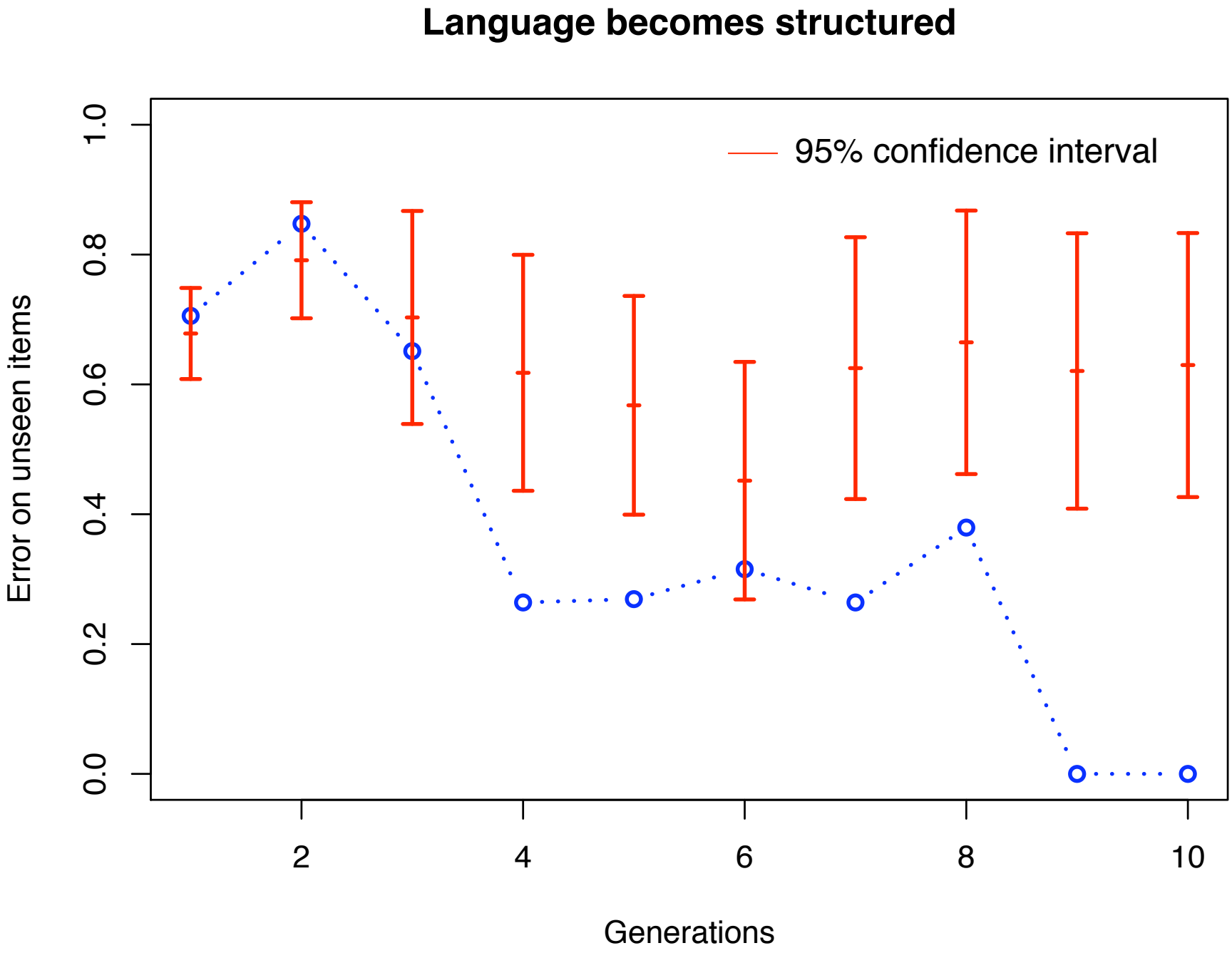
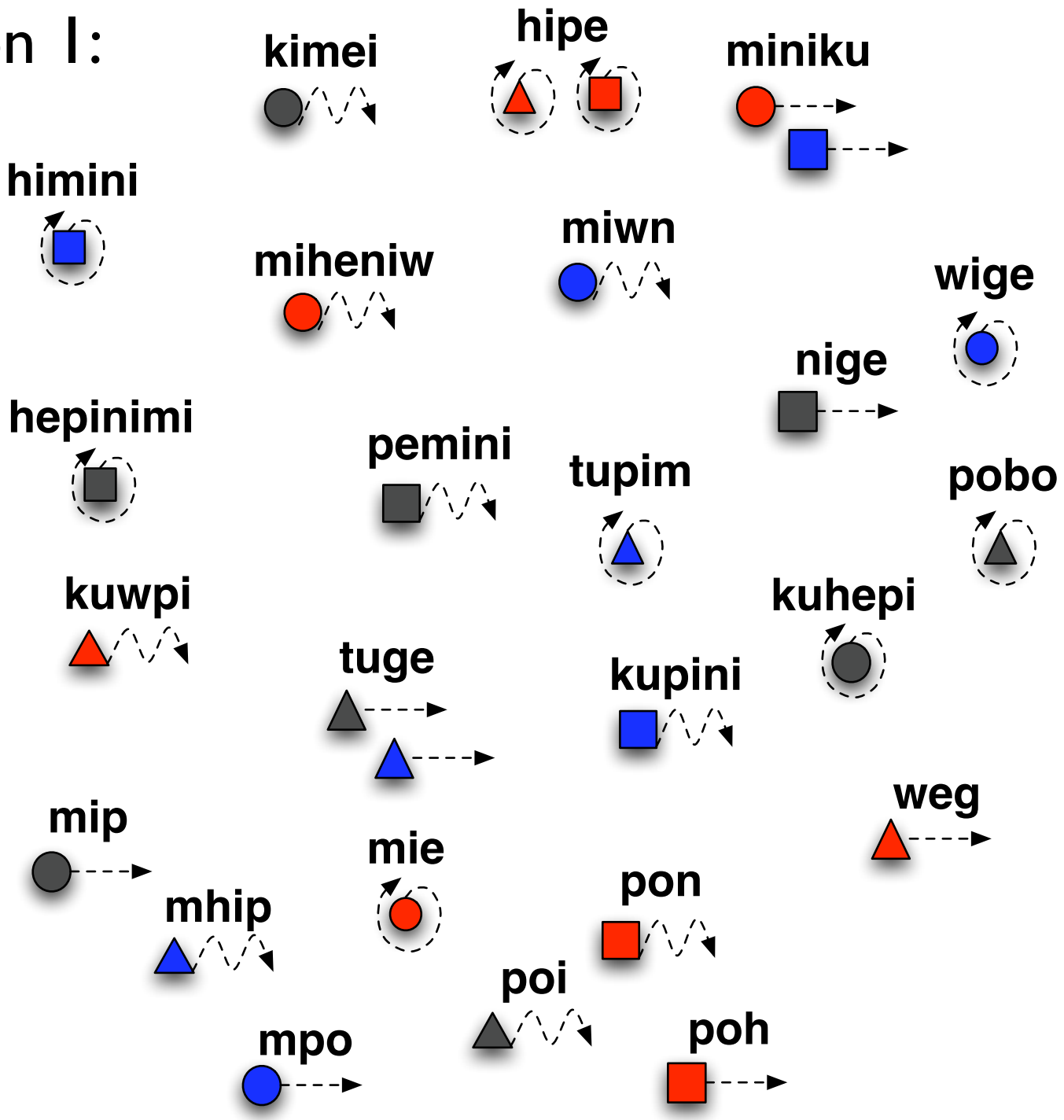
How has language become easier?

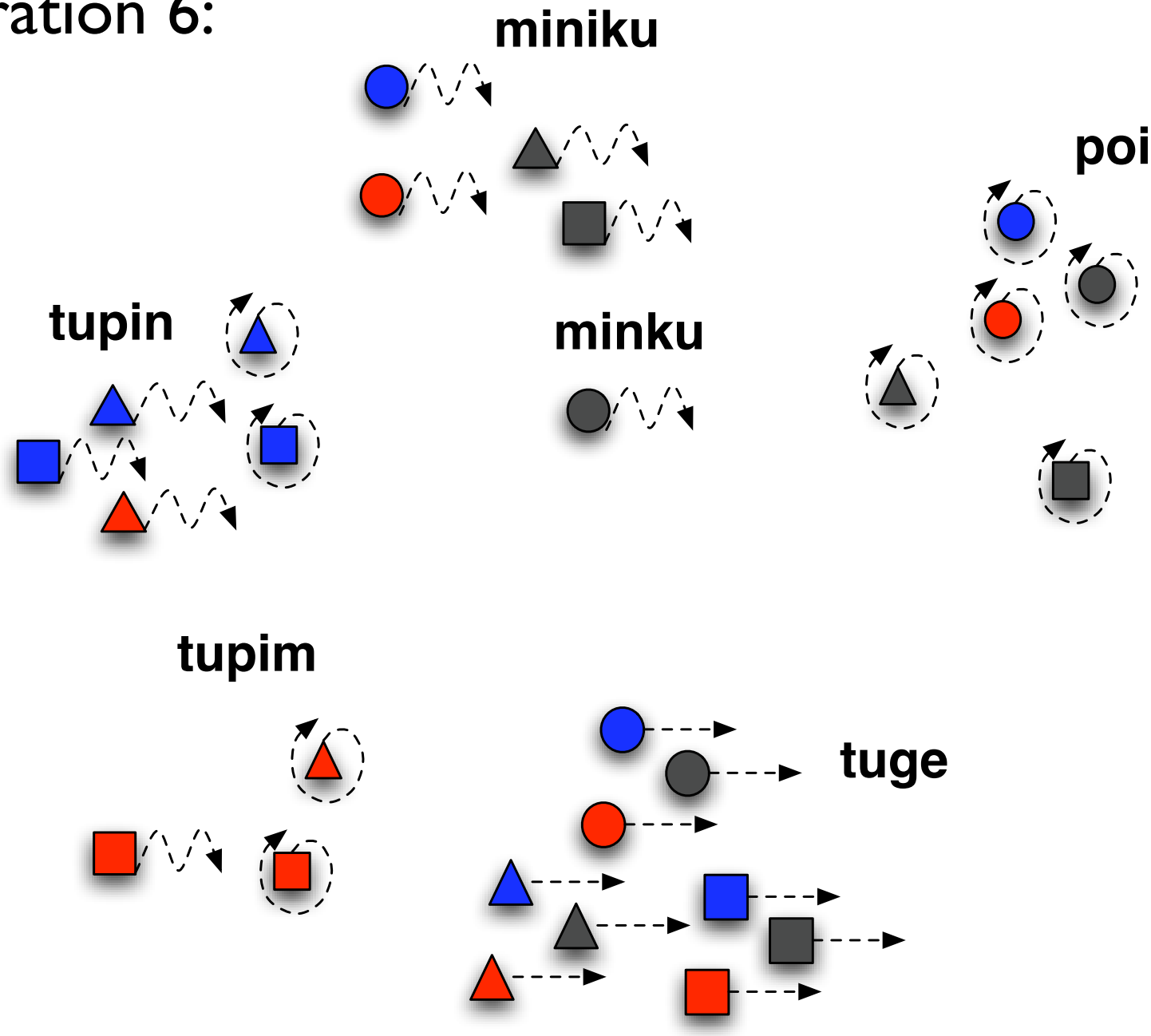
- Looks like it might be just that there are fewer words.
- If this were all that was going on, then subjects' performance on unseen items should be random
- This doesn't appear to be the case...


Language becomes structured
95% confidence interval
Error on unseen items
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
Generations

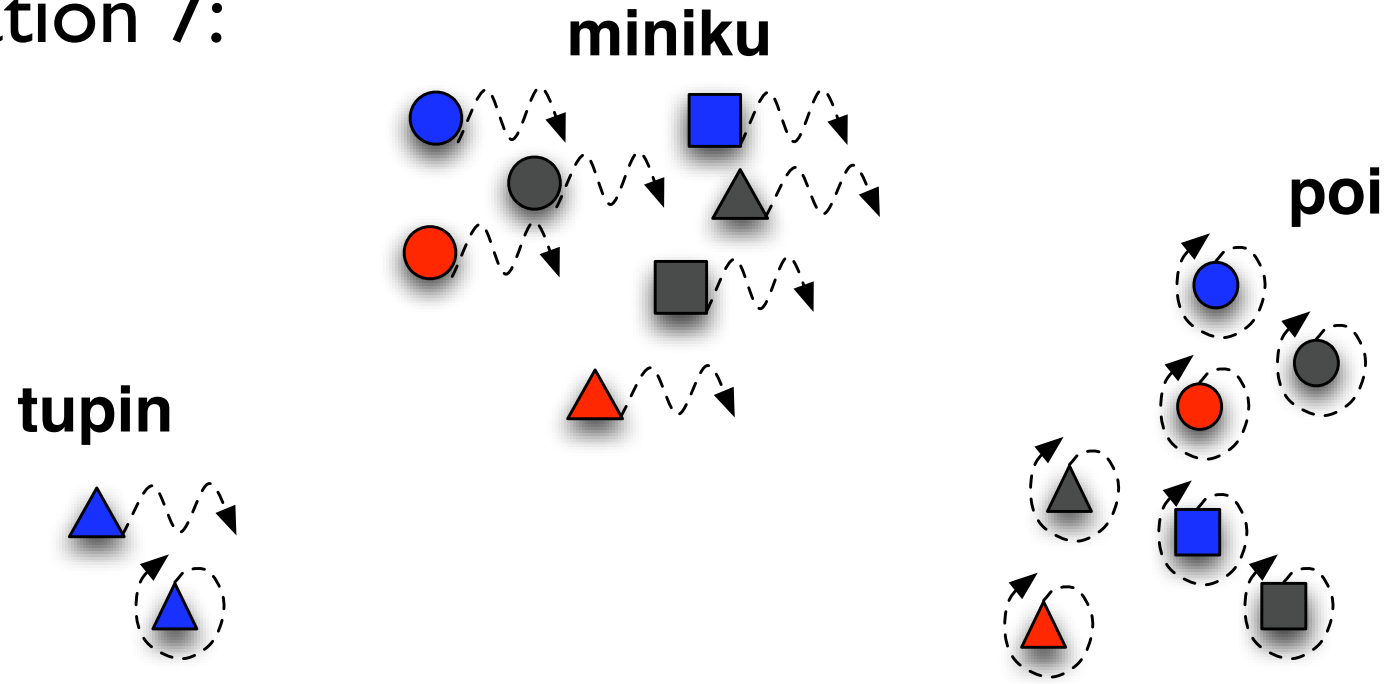
After Generation 1:



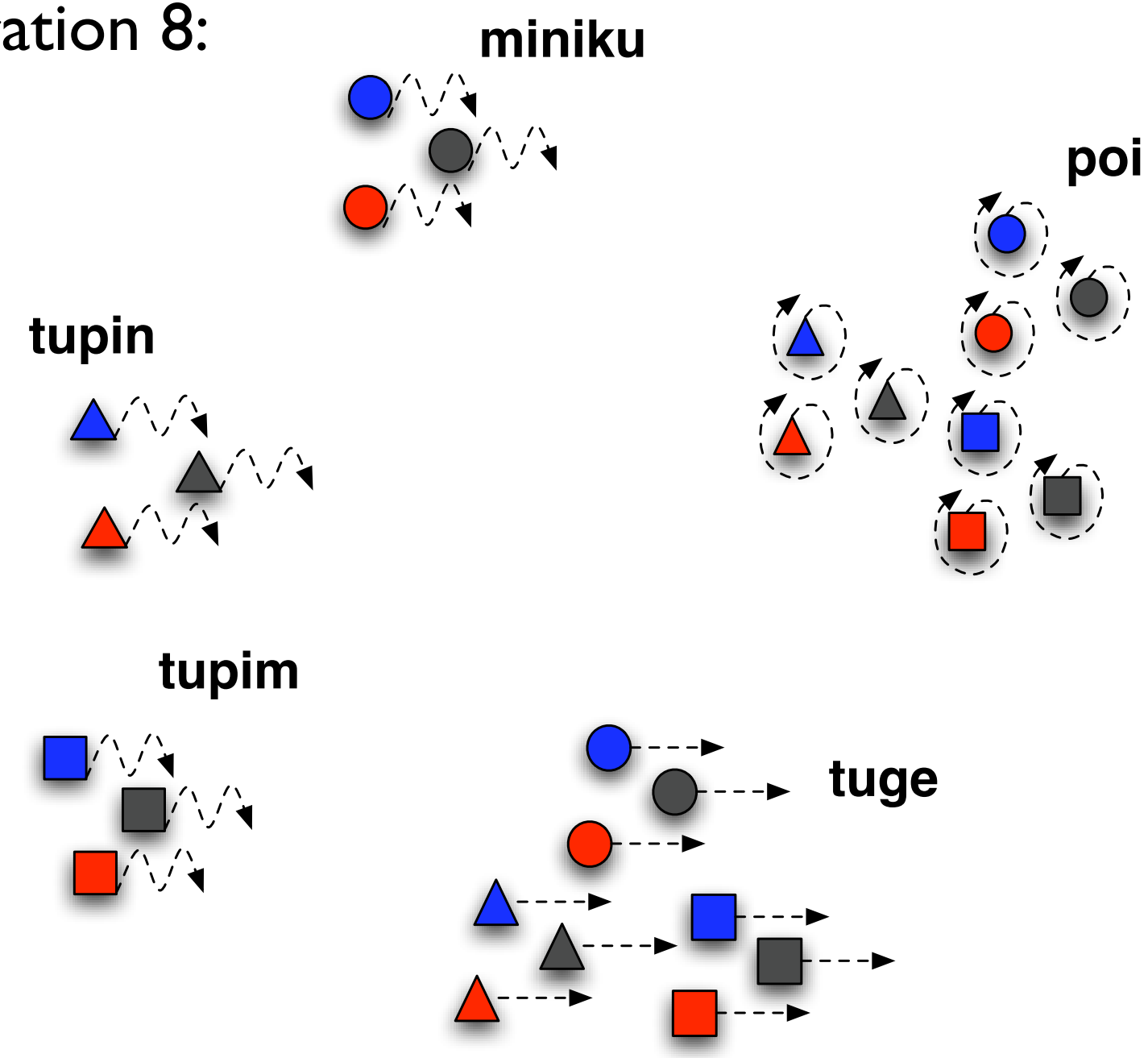
After Generation 6:



After Generation 7:

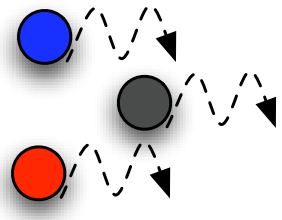


After Generation 8:

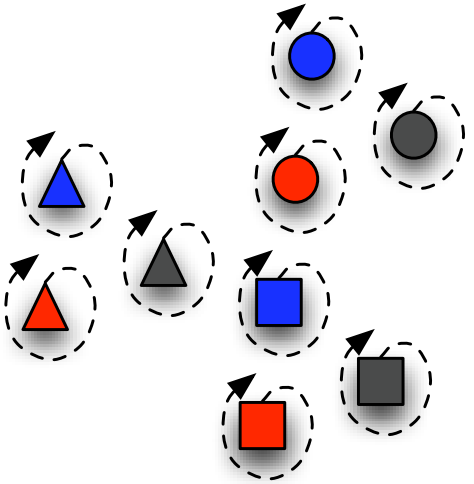


After Generation 9:

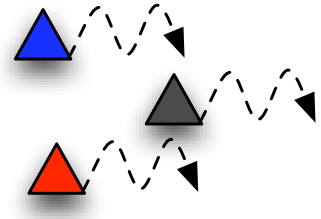
miniku



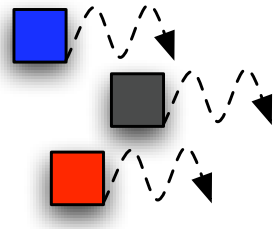
poi



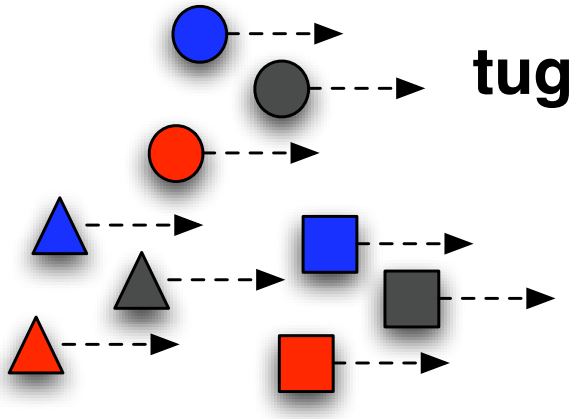
tupin



tupim



tuge



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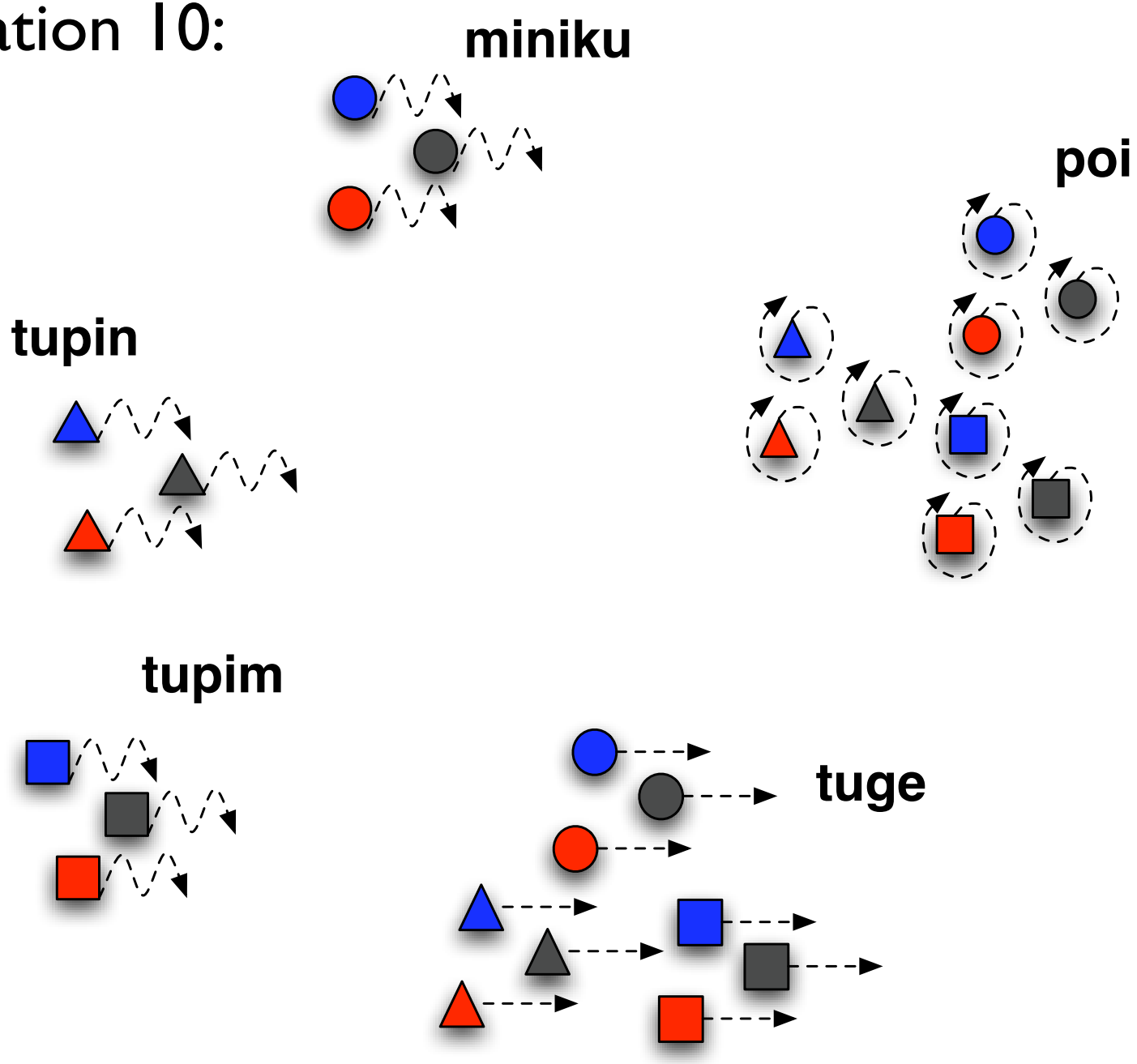


Language adapts to be structured

- Language adapts
  - **Subjects are not aware of this** (they aren't even aware they are being shown unseen items!)
  - Structured ambiguity is an *adaptation by language to aid its own survival*
- Cumulative cultural adaptation without intention

More interesting structure?

- In reality language exhibits structure (e.g. morphology, syntax) that makes it learnable *and* expressive
- There's no pressure for expressivity in the experiment

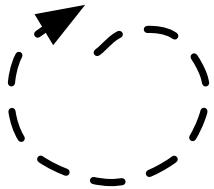
More interesting structure?

- In reality language exhibits structure (e.g. morphology, syntax) that makes it learnable *and* expressive
- There's no pressure for expressivity in the experiment
- Simple modification: filter out all ambiguous items from SEEN set before subjects see them

After Generation 4:

wuneko	huneko	puneko
wineko	huneko	poneko
wikeko	kuneko	poneko

winukuki	hunekuki	punekuki
winekuki	kunkuki	ponekuki
wikekuki	kunekuki	ponekuki



winekiko	kunekiko	puniko
winekiko	kunkiko	pokiko
wikiko	kunekiko	pokiko

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- It must be learned even though:
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  - ambiguous signals are filtered out
- Morphological/syntactic structure is a solution to this problem

The emergence of culturally transmitted communication

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- The previous paradigm assumed that individuals:
  - want to communicate
  - know what to communicate about
  - have a dedicated "channel" for communication
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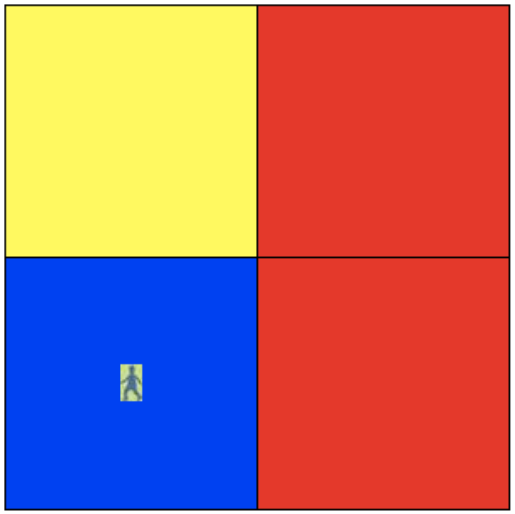
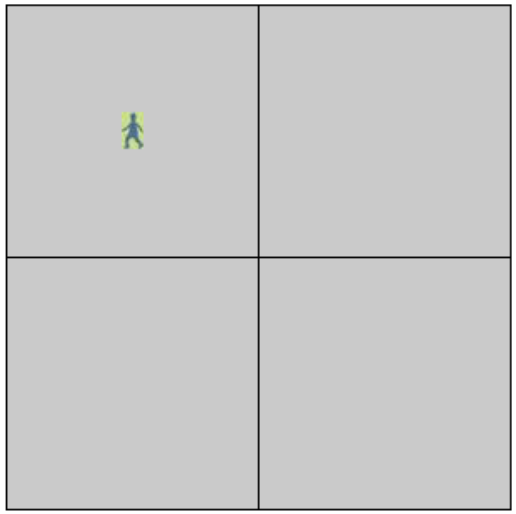
- The previous paradigm assumed that individuals:
  - want to communicate
  - know what to communicate about
  - have a dedicated "channel" for communication
  - want to share their communication system.
- In other words, they are already *symbolic learners*
  - Can we explore the genuine emergence of symbols in the lab?

A test-bed for the emergence of symbolic communication

- Participants play a two-player cooperative computer game where the other player is in another room
- Steer a character round a room with different coloured floor tiles and try to finish up on the same colour as the other player
- Inspired by Galantucci (2005) but *without a communication channel*

Player 1 sees:

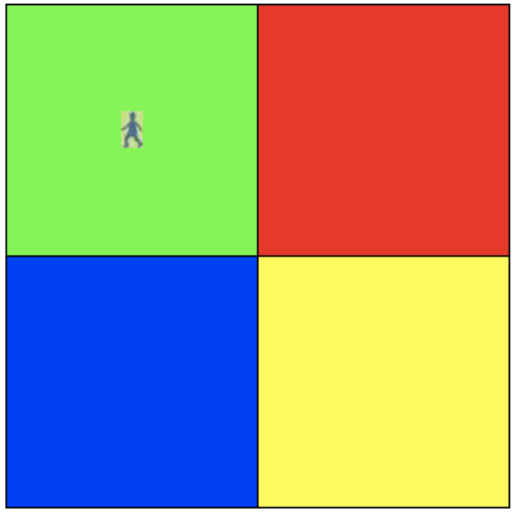


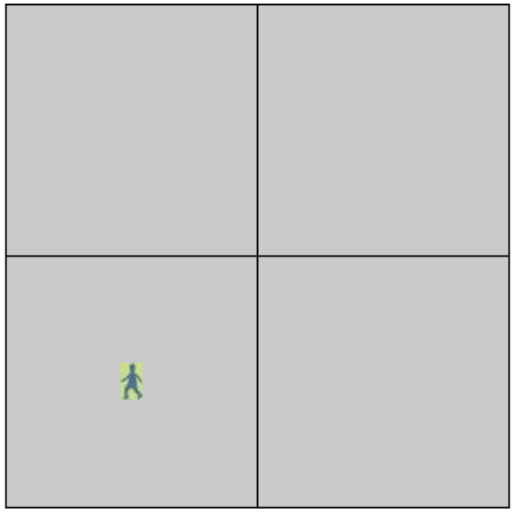


Points in succession: 0 Highest: 3

Press space when you're finished

Player 2 sees:





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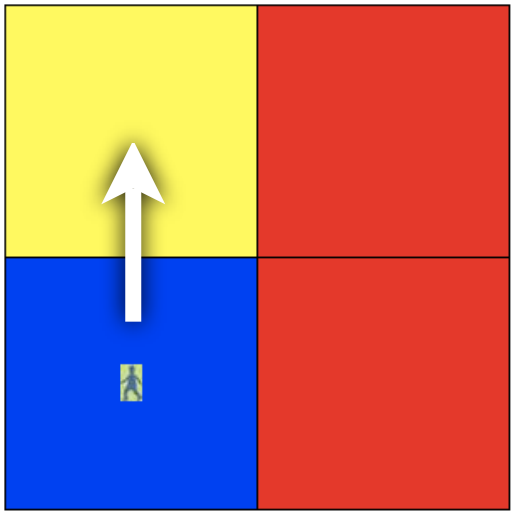

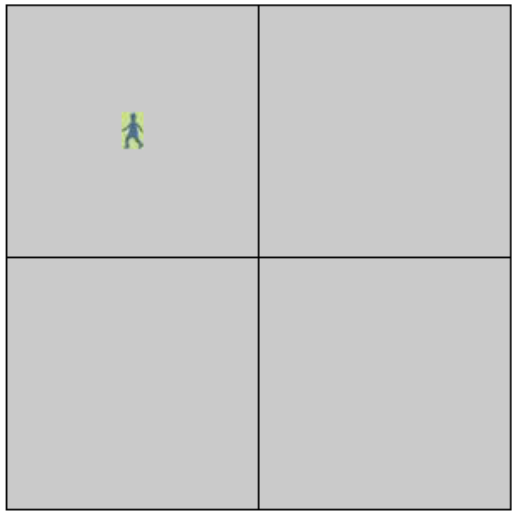

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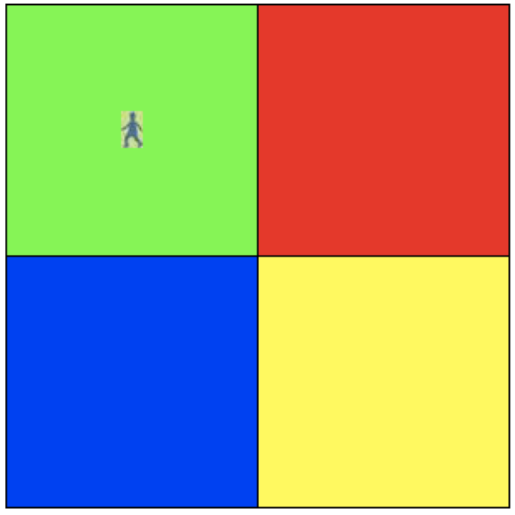
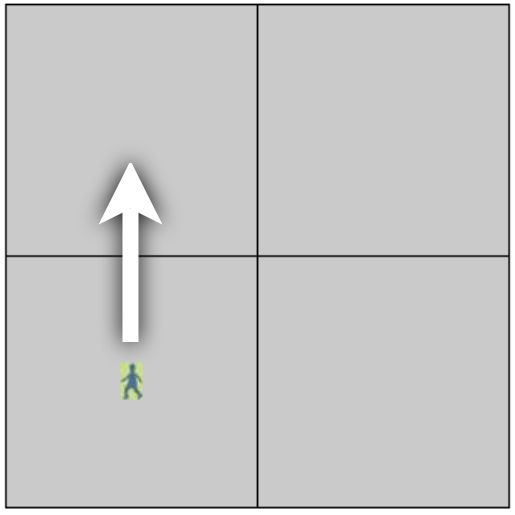
Player 2 sees:

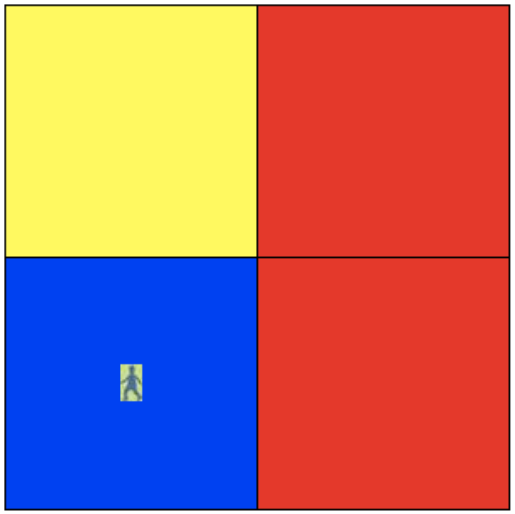


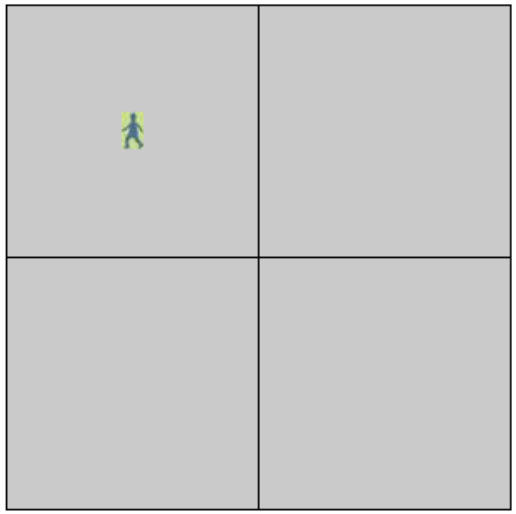


Points in succession: 0 Highest: 3

Press space when you're finished

Player 1 sees:

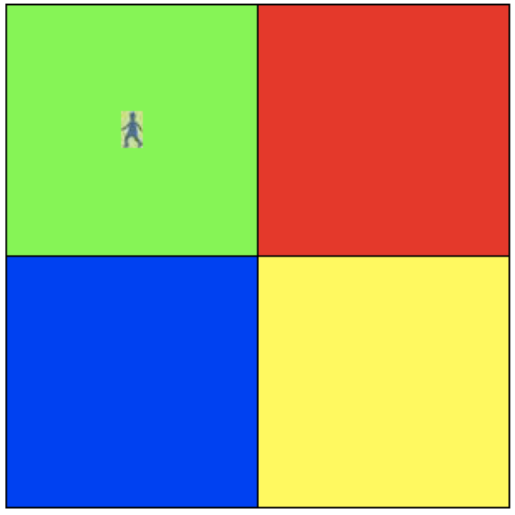


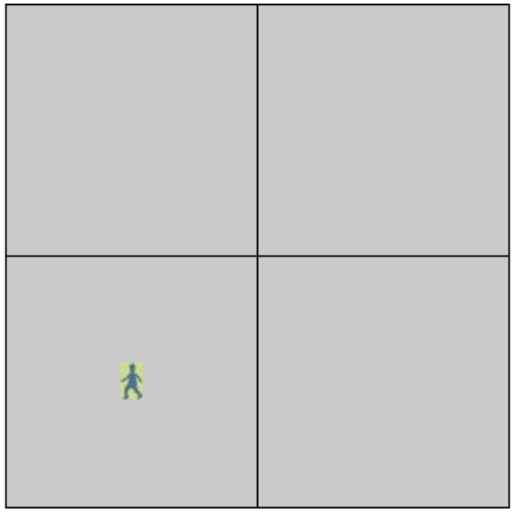


Points in succession: 0 Highest: 3

Press space when you're finished

Player 2 sees:





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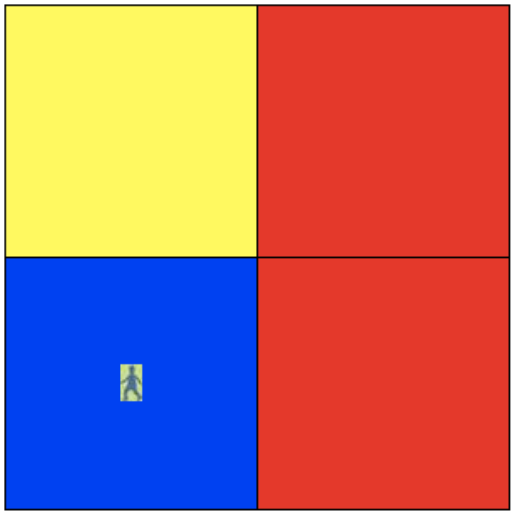

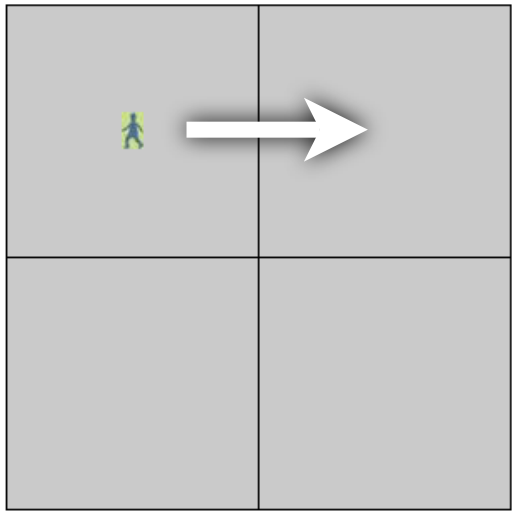

Points in succession: 0 Highest: 3

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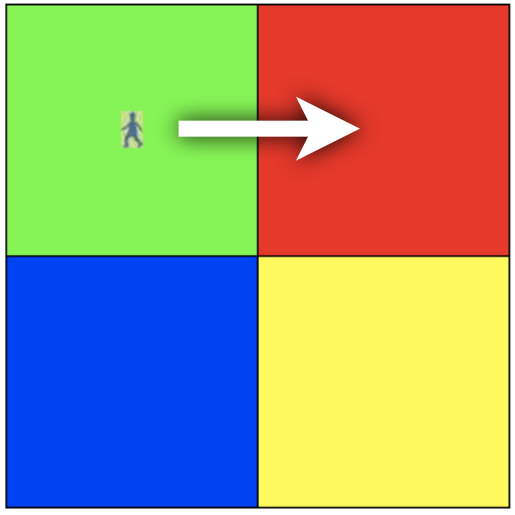

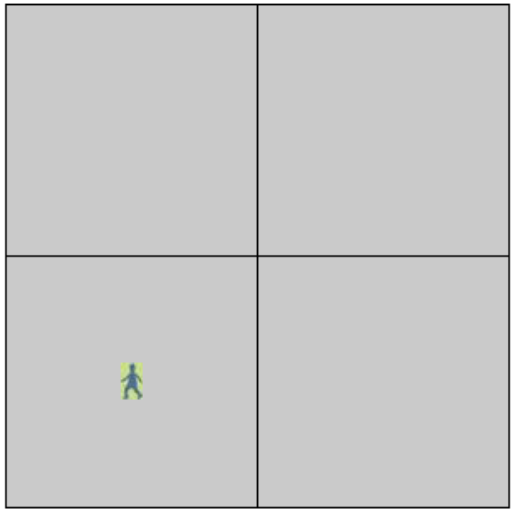

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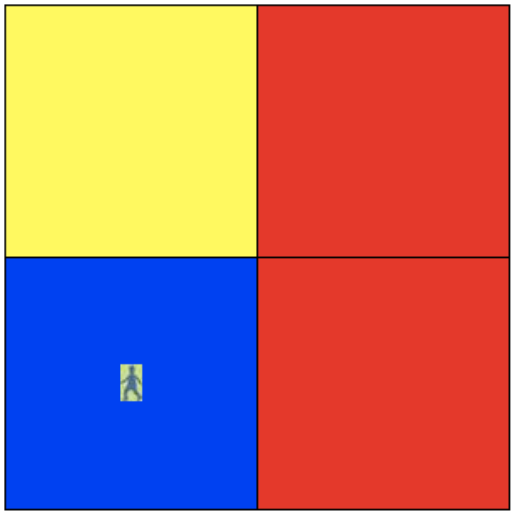

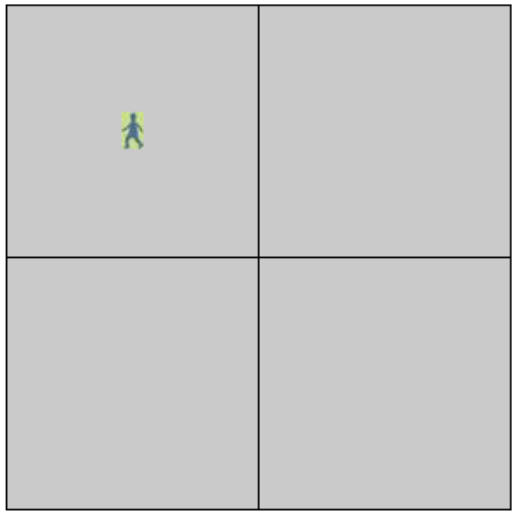

Points in succession: 0 Highest: 3

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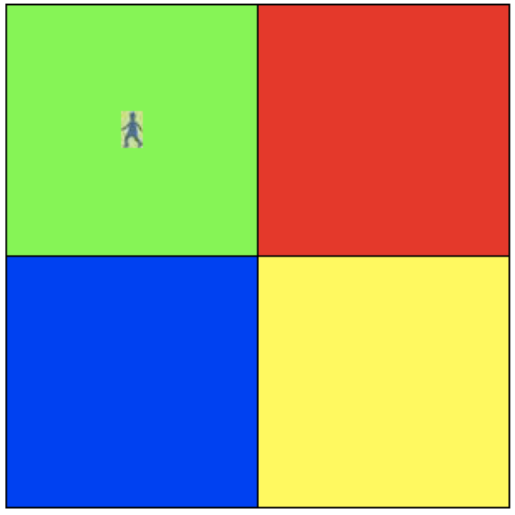
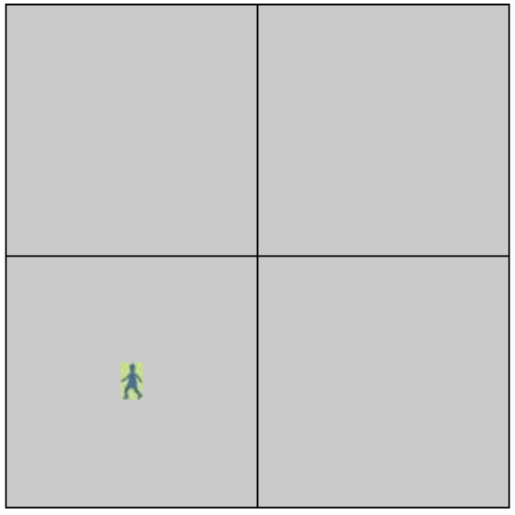
Player 2 sees:





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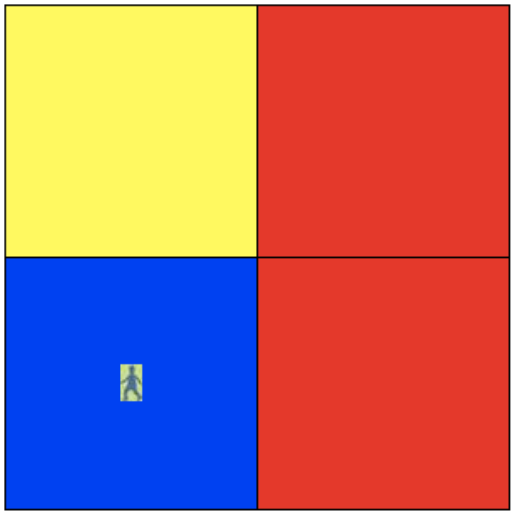
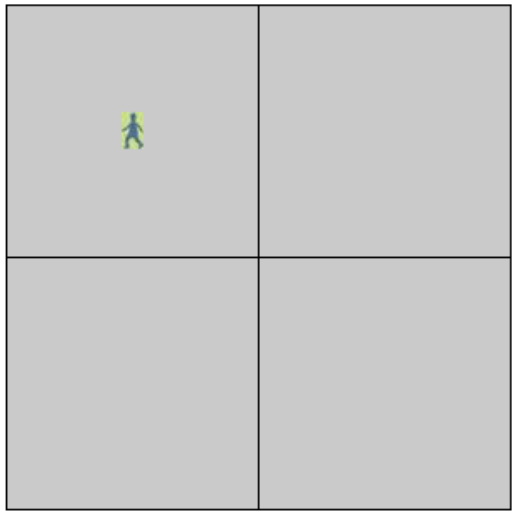
Press space when you're finished

Rules

- Score if on same colour after both press finish
- Always at least one colour that's in both rooms (but equally there may be colours that are unique to room)
- Colour assignment is completely random after each turn
- After turn, other player's colours are revealed
- It *is* possible to find a strategy for winning on every turn

Player 1 sees:

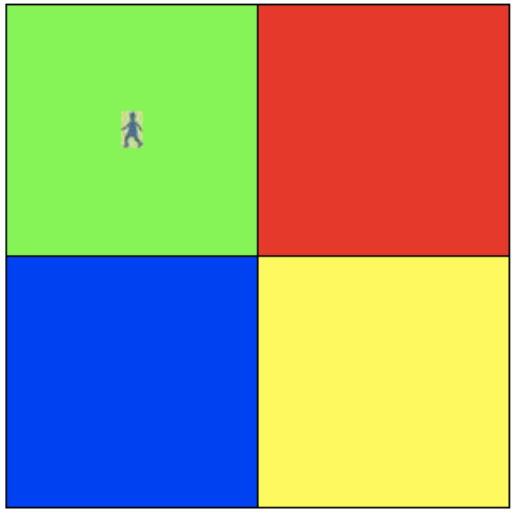


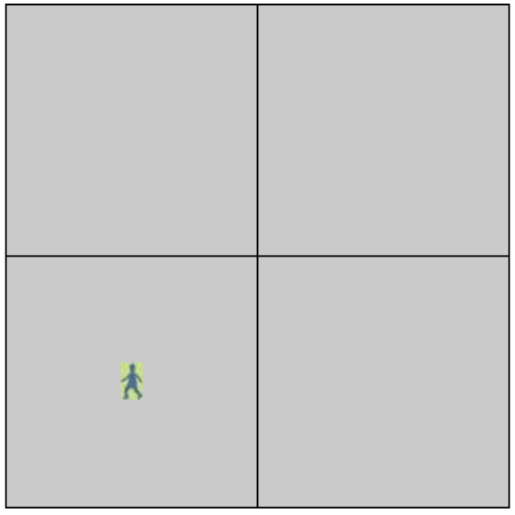


Points in succession: 0 Highest: 3

Press space when you're finished

Player 2 sees:





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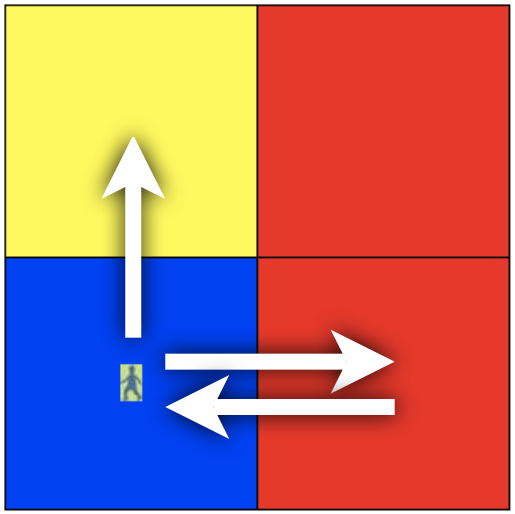
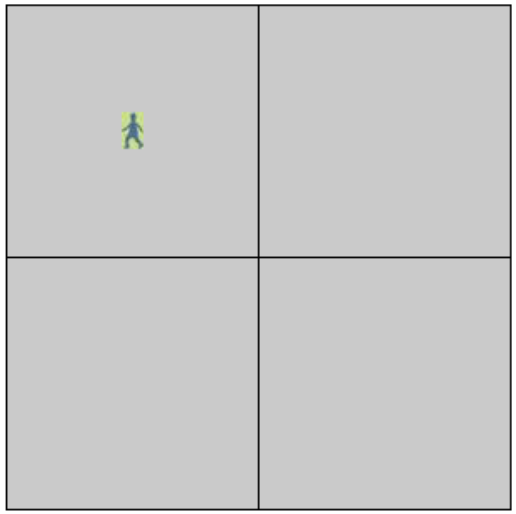
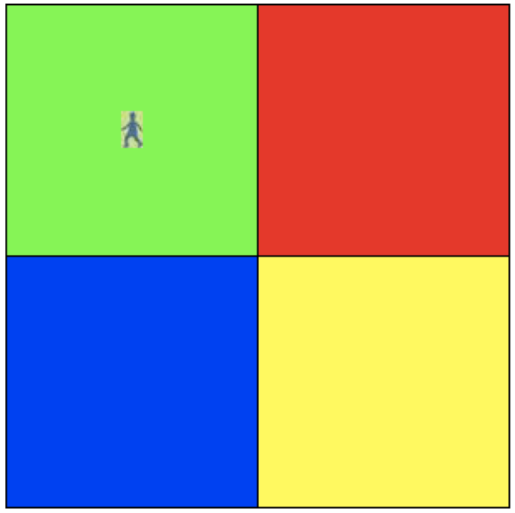


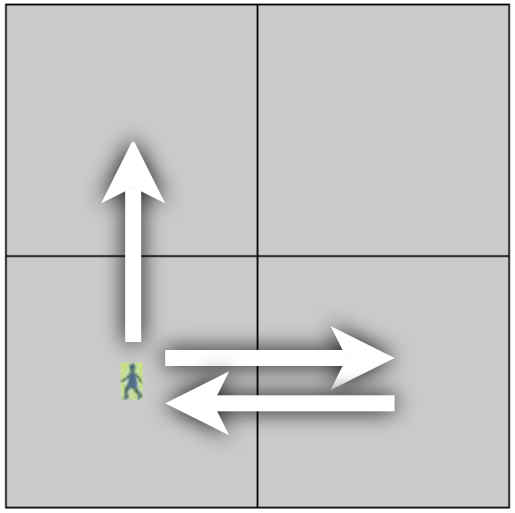


Points in succession: 0 Highest: 3

Press space when you're finished

Player 2 sees:





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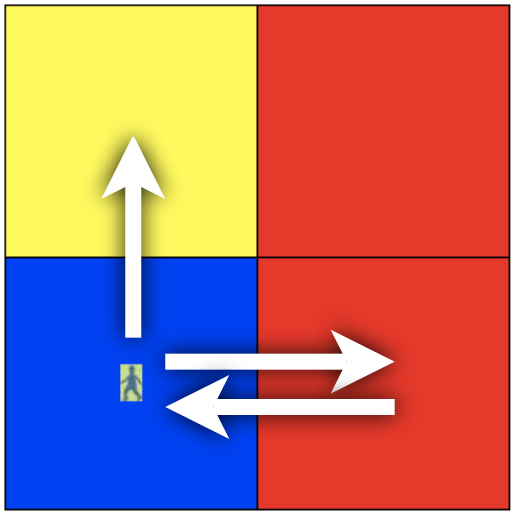

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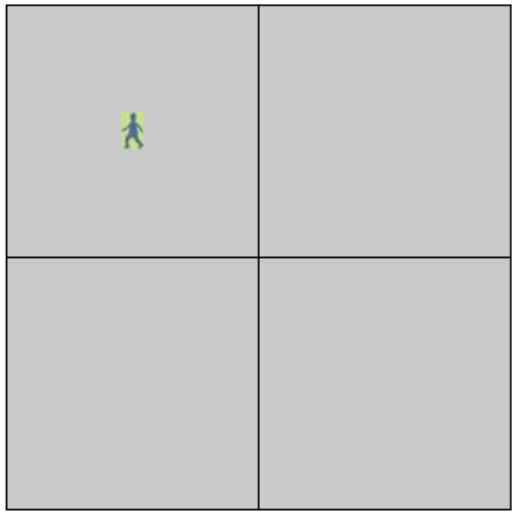
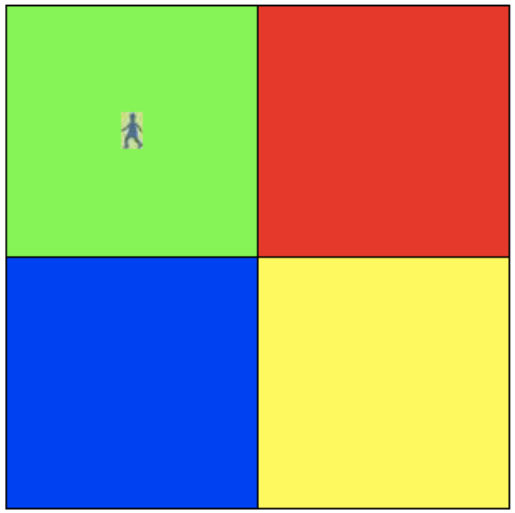


Player 2 sees:



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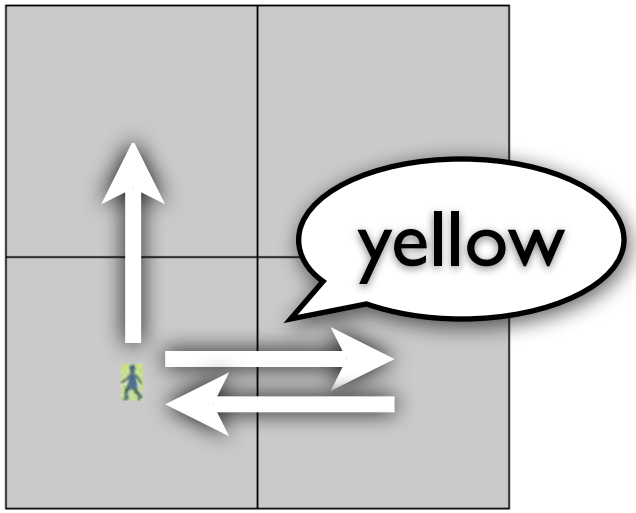
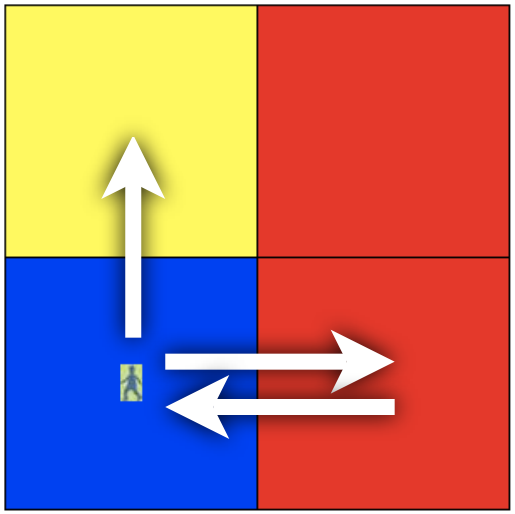


Player 1 sees:



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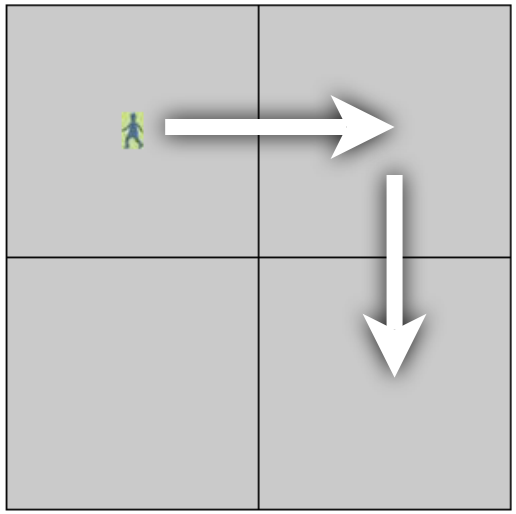
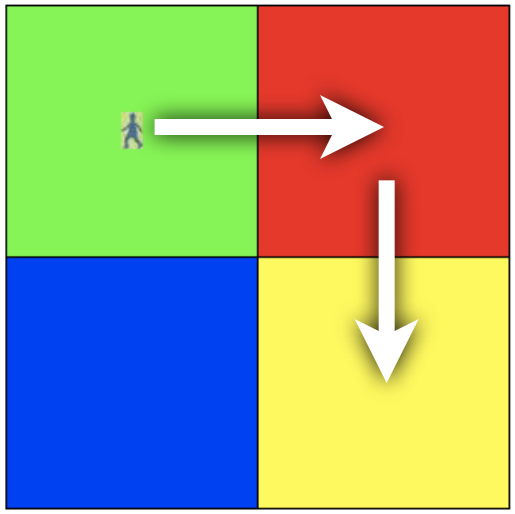


Player 2 sees:



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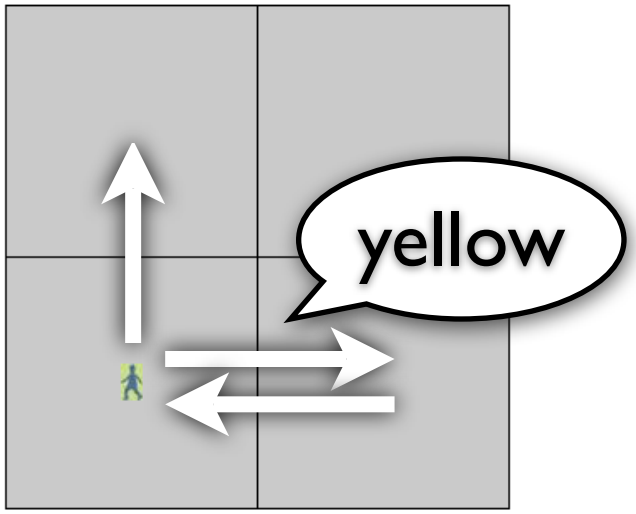
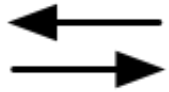
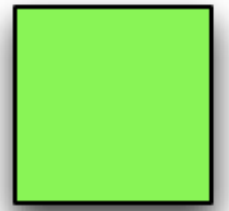


Move & stop (default strategy)

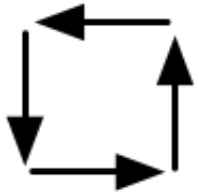
Oscillations

or

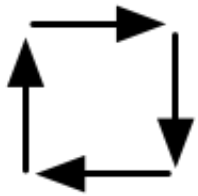


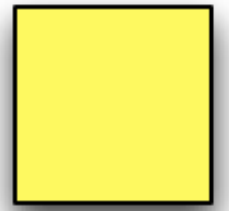


Loop

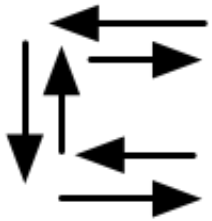


or





C-shape



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- Demonstrates again the fundamental importance of the socio/cultural process

Conclusions

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  - This means we need to abandon some of the idealisations of the orthodox, individual-based approach

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- Cultural evolution is just as important (if not more so) than biological evolution in understanding human language
  - This means we need to abandon some of the idealisations of the orthodox, individual-based approach
- Can we study cultural evolution in the lab?
  - Yes! Novel experimental techniques inspired by computational models give us a way.
  - In a very real sense we can observe the evolution of language in miniature in laboratory conditions.