

# Online Experiments for Language Scientists

Lecture 8: Iterated learning

Kenny Smith

[kenny.smith@ed.ac.uk](mailto:kenny.smith@ed.ac.uk)

# Beckner et al (2017)

Beckner, C., Pierrehumbert, J., & Hay, J. (2017). The emergence of linguistic structure in an online iterated learning task. *Journal of Language Evolution*, 2, 160–176.

An iterated artificial language learning experiment

- Does compositional structure emerge ‘for free’ from person-to-person transmission?



**Clay Beckner**  
(now at Warwick)



**Janet Pierrehumbert**  
(Oxford)

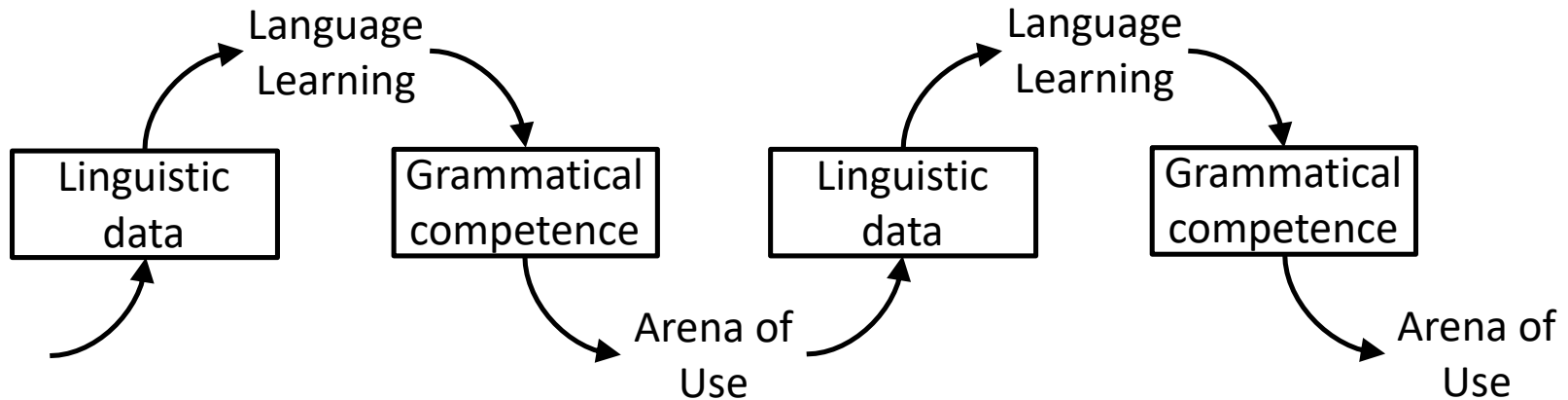


**Jen Hay**  
(Canterbury, NZ)

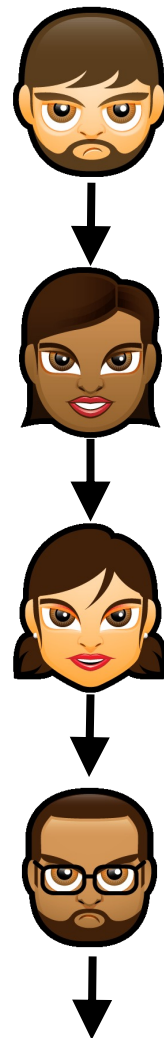
Language is transmitted via repeated **learning** and **use**

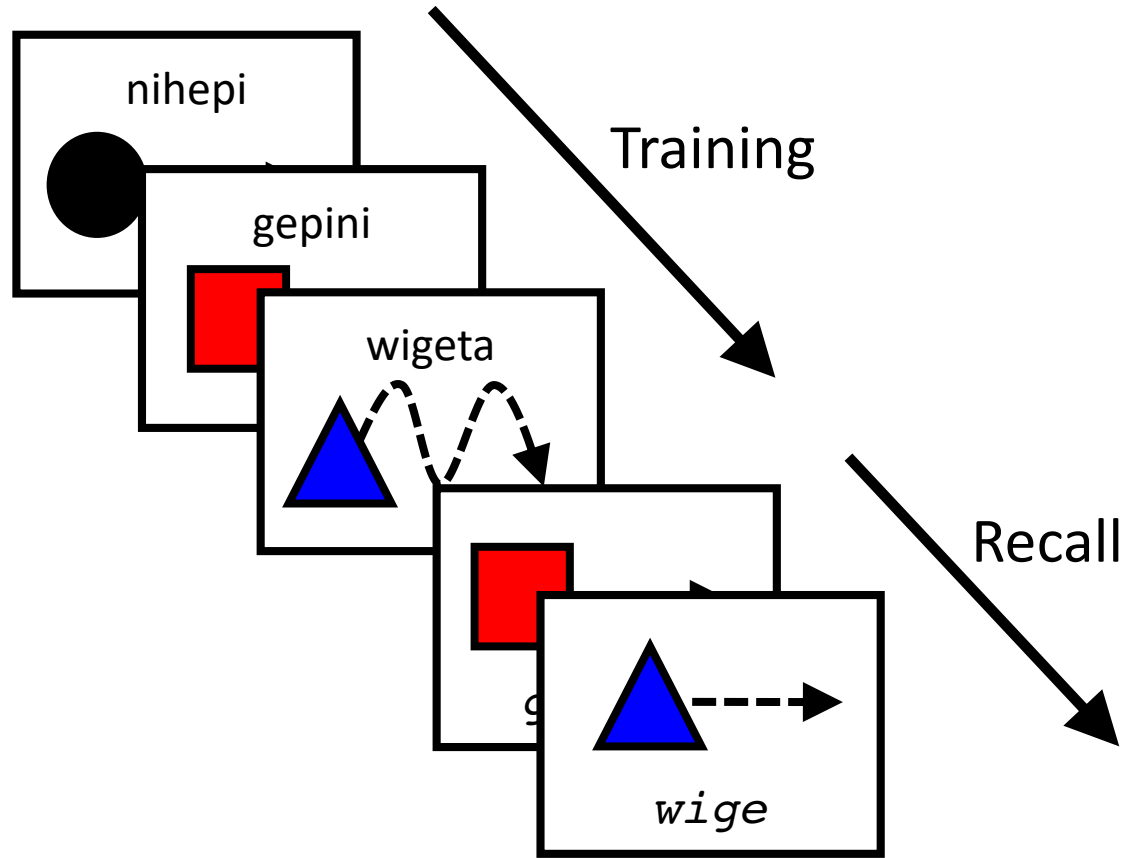
Language is shaped by these processes

**The cycle of learning and use produces structure**



Iterated learning





Kirby, S., Cornish, H., & Smith, K. (2008). Cumulative cultural evolution in the laboratory: An experimental approach to the origins of structure in human language. *PNAS*, 105, 10681-10686.

Demo using this week's practical code

# Initial holistic language from chain 4

--→	wimaku	miniki	gepinini	□
	nihepi	wigemi	mahekuki	○
	wikima	nipikuge	hema	△
↻	miwiniku	pinipi	kihemiwi	□
	kinimapi	wikuki	kikumi	○
	miwimi	nipi	wige	△
↻	gepihemi	kunige	miki	□
	pikuhemi	kimaki	pimikihe	○
	mihe	winige	kinimage	△

# Generation 1 language from chain 4

--->	nige	miniku	poh	□
	mip	mpo	miniku	○
	tuge	tuge	weg	△
~>	pemini	kupini	pon	□
	kimei	miwn	miheniw	○
	poi	mhip	kuwpi	△
↻	hepinimi	himini	hipe	□
	kuhepi	wige	mie	○
	pobo	tupim	hipe	△



# Generation 2 language from chain 4

-->	nige	tuge	tuge	□
	nige	nige	tuge	○
	nige	tuge	mpo	△
↗↘	nige	tuge	mihenu	□
	hepini	miniku	hepini	○
	poi	mpo	tupim	△
↻	hepini	miniku	tupim	□
	hepini	tupim	tupim	○
	nige	tupim	poi	△

# Generation 3 language from chain 4

-->	mihenu	tuge	tuge	□
	tuge	tuge	tuge	○
	nige	tuge	tuge	△
~>	miniku	tuge	minihu	□
	tuge	tupim	tupim	○
	poi	tuge	miniku	△
↻	mihenu	tupim	tupim	□
	tupim	tupim	tupim	○
	poi	tupim	tupim	△

# Generation 4 language from chain 4

-->	tuge	tuge	tuge	□
	tuge	tuge	tuge	○
		tuge	tuge	△
↗↘	mihunu	tupim	miniku	□
	tupim	tupim	tupim	○
	poi	miniku	miniku	△
↻	tupim	tupim	tupim	□
	tupim	tupim	tupim	○
	poi	tupim	tupim	△

# Generation 5 language from chain 4

-->	tuge	tuge	tuge	□
	tuge	tuge	tuge	○
	tuge	tuge	tuge	△
↗↘	minuhu	tupim	tupim	□
	tupim	tupim	tupim	○
	miniku	tupim	miniku	△
↻	tupim	tupim	tupim	□
	tupim	tupim	tupim	○
	poi	tupim	tupim	△

# Generation 6 language from chain 4

--→	tuge	tuge	tuge	□
	tuge	tuge	tuge	○
	tuge	tuge	tuge	△
↗↘→	miniku	tupin	tupim	□
	miniku	miniku	miniku	○
	miniku	tupin	tupin	△
↻	poi	tupin	tupim	□
	poi	poi	poi	○
	poi	tupin	tupim	△

# Generation 7 language from chain 4

→	tuge	tuge	tuge	□
	tuge	tuge	tuge	○
	tuge	tuge	tuge	△
↗	miniku	miniku	tupim	□
	miniku	miniku	miniku	○
	miniku	tupin	miniku	△
↻	poi	poi	tupim	□
	poi	poi	poi	○
	poi	tupin	poi	△

# Generation 8 language from chain 4

→	tuge	tuge	tuge	□
	tuge	tuge	tuge	○
	tuge	tuge	tuge	△
↗	tupim	tupim	tupim	□
	miniku	miniku	miniku	○
	tupin	tupin	tupin	△
↻	poi	poi	poi	□
	poi	poi	poi	○
	poi	poi	poi	△

# Generation 9 language from chain 4

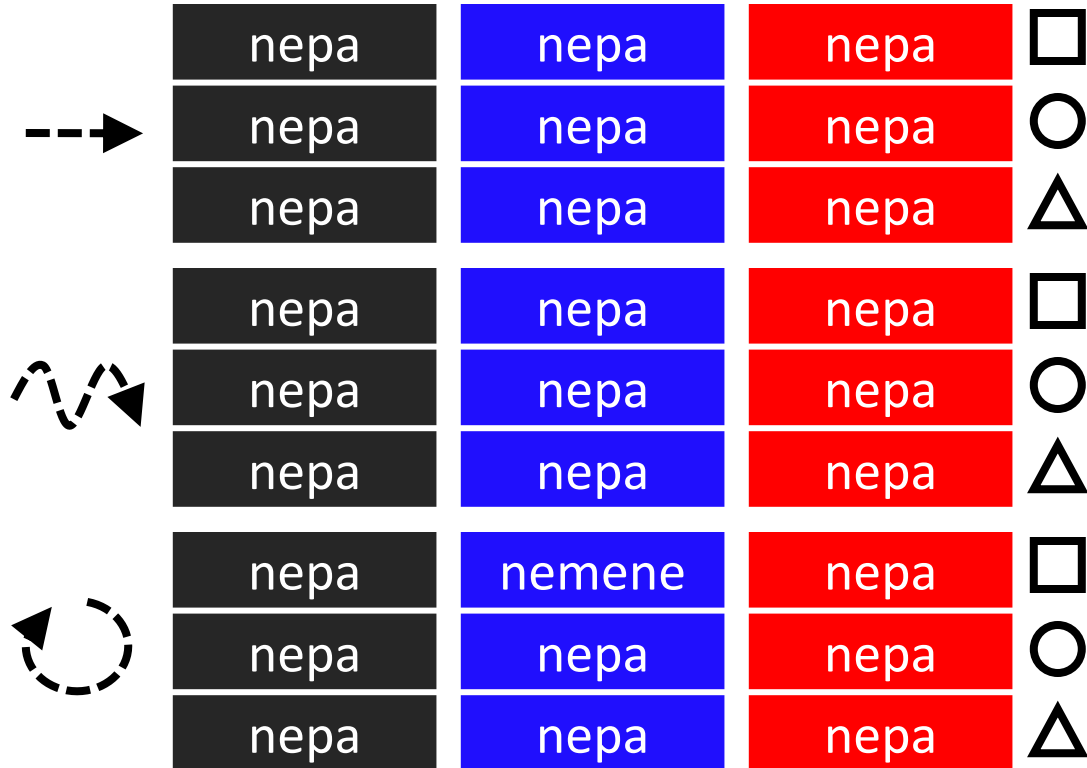
→	tuge	tuge	tuge	□
	tuge	tuge	tuge	○
	tuge	tuge	tuge	△
↗	tupim	tupim	tupim	□
	miniku	miniku	miniku	○
	tupin	tupin	tupin	△
↻	poi	poi	poi	□
	poi	poi	poi	○
	poi	poi	poi	△



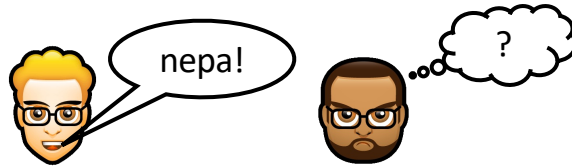
# Generation 10 language from chain 4

→	tuge	tuge	tuge	□
	tuge	tuge	tuge	○
	tuge	tuge	tuge	△
↻	tupim	tupim	tupim	□
	miniku	miniku	miniku	○
	tupin	tupin	tupin	△
↻	poi	poi	poi	□
	poi	poi	poi	○
	poi	poi	poi	△

# Final language from chain 1 (!)



The languages become **degenerate**



# Generation 9 language from chain 5 (with homonymy filter)

-->	ne-re-ki	la-re-ki	renana	□
	ne-he-ki	la-ho-ki	re-ne-ki	○
	ne-ke-ki	la-ke-ki	ra-he-ki	△
↗↘	ne-re-plo	la-ne-plo	re--plo	□
	ne-ho-plo	la-ho-plo	re-ho-plo	○
	ne-ki-plo	la-ki-plo	ra-ho-plo	△
↻	ne--pilu	la-ne-pilu	re--pilu	□
	ne-ho-pilu	la-ho-pilu	re-he-pilu	○
	ne-ki-pilu	la-ki-pilu	ra-ho-pilu	△

# Beckner et al. (2017)

Reanalysis/gentle roasting of Kirby, Cornish & Smith (2008)

- Our sample size was tiny
- Our statistics were rudimentary
- They find an interesting (?) difference between semantic dimensions

## **Replication**

- Participants recruited from MTurk
- N=240 (2 conditions, 12 chains per condition, 10 participants per chain)
- 22-25 minutes, paid \$3

# Measuring structure

“the dog chew-ed the bone” – “the dog lick-ed the bone”

Meaning distance = 1 (predicate)

Signal distance = 1 (verb stem)

“the dog chew-ed the bone” - “the dog lick-s the bone”

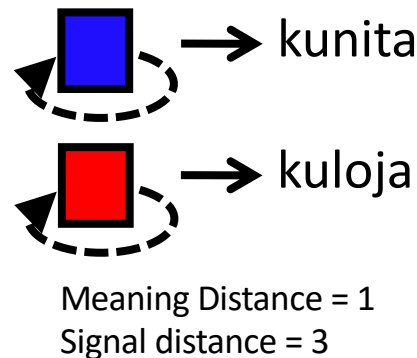
Meaning distance = 2 (predicate, tense)

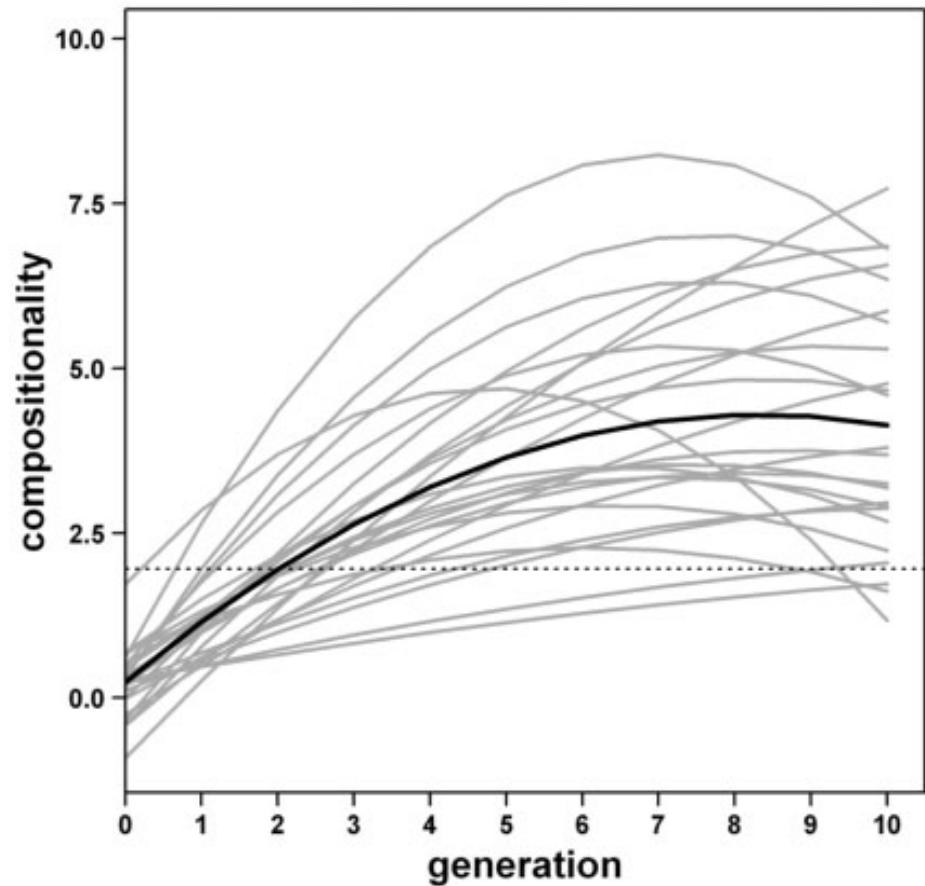
Signal distance = 2 (verb stem, suffix)

**Pairwise meaning and signal distances will be highly correlated in a compositional system:** similar meanings map to similar signals (and dissimilar meanings map to dissimilar signals)

# Measuring structure

- For every pair of meaning-signal pairs
  - Measure meaning distance (Hamming distance)
  - Measure signal distance (Levenshtein string-edit distance)
  - Correlate these distances
- Evaluate statistical significance of that correlation
  - Randomise label assignments, recalculate measure, repeat 1000 times to give distribution
  - Calculate z-score of veridical correlation





	'red'	'green'	'blue'	
'berry'	shen-to	shen-ta	shen-to	'1'
	shen-tra	shen-tro	shen-tra	'2'
	shen-trio	shen-trio	shen-trio	'3'
'key'	div-tro	div-tro	div-tro	'1'
	dev-tro	dev-tro	dev-etrio	'2'
	dev-stra	div-stra	dev-stra	'3'
'phone'	lolni-tro	lolni-tro	lolni-to	'1'
	lolne-stra	lolni-tro	lolne-stro	'2'
	lolni-tra	lolni-stra	lolni-stra	'3'



# Beckner et al.'s conclusions

Iterated learning **does** produce structure

- Our 2008 result replicates with a proper sample size
- The method also works online...
- ... but for this kind of challenging task, MTurk data is noisier?

Time for Q&A/discussion on this week's reading

# Next up

Wednesday, 9am: lab

- Iterated learning, manipulating CSVs and looping trials

Next week: final lecture and lab 🥲

- Zipf's Law of Abbreviation, real-time dyadic interaction