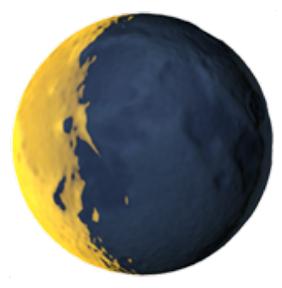


Why do languages tolerate heterography? An experimental investigation of the cultural evolution of informative orthographies

Jon W. Carr & Kathleen Rastle
Royal Holloway, University of London



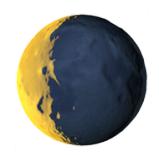
LEVERHULME
TRUST



<night>



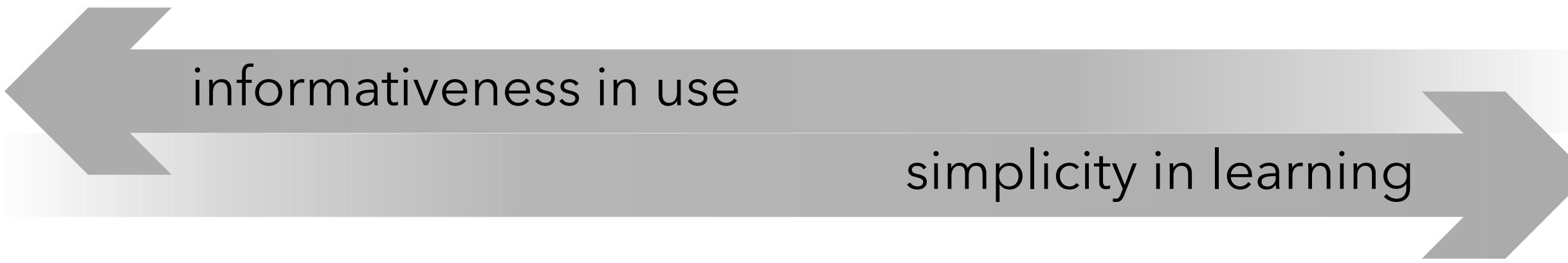
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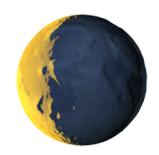


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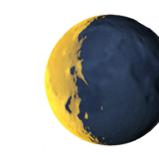




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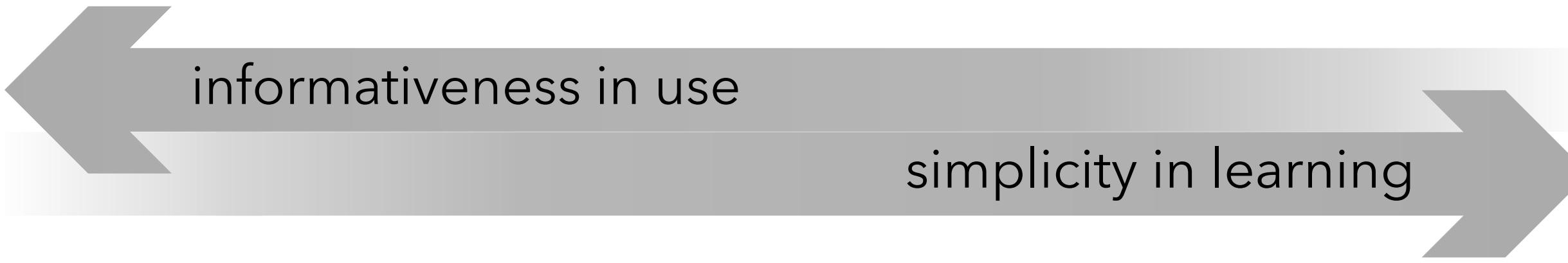
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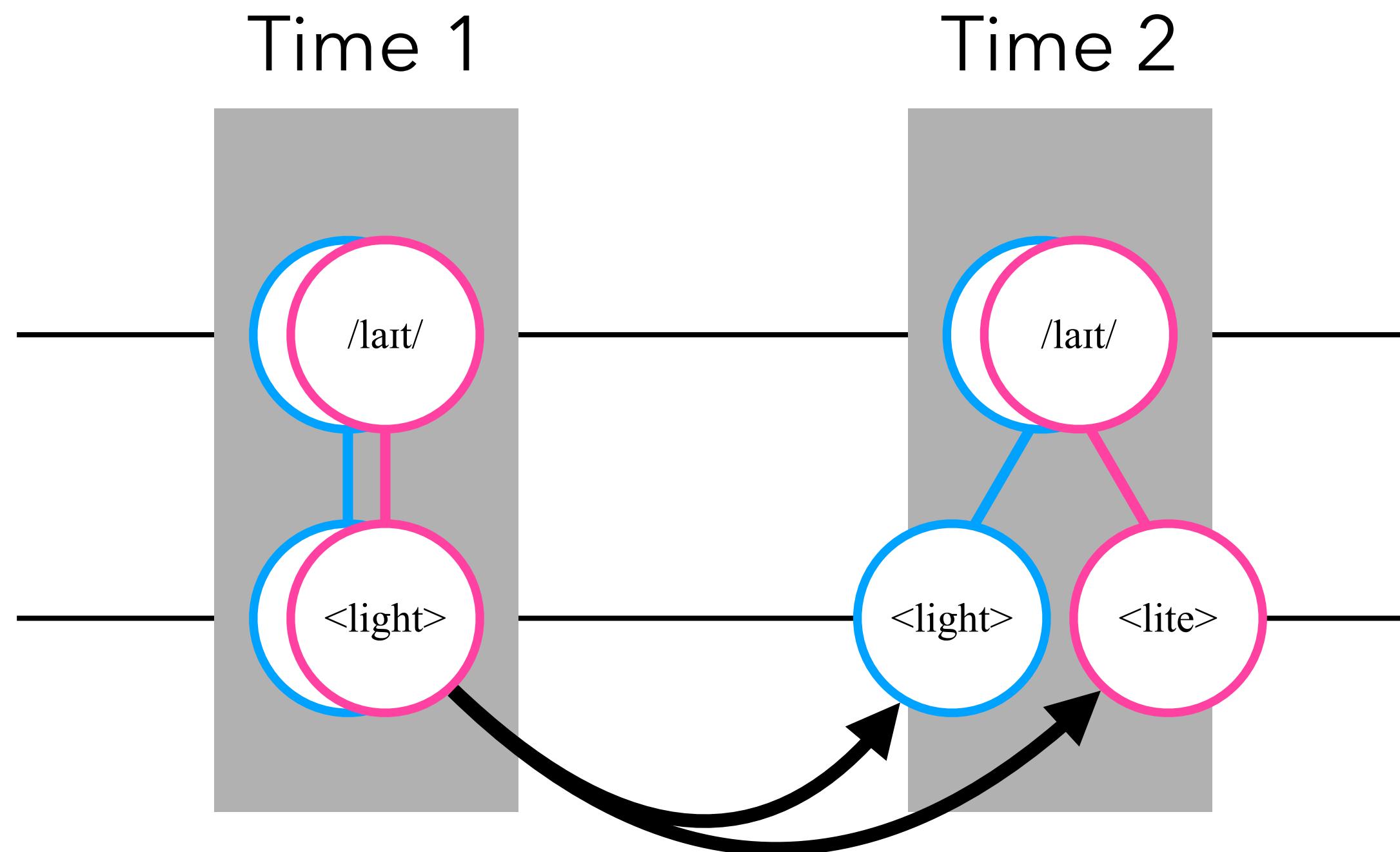
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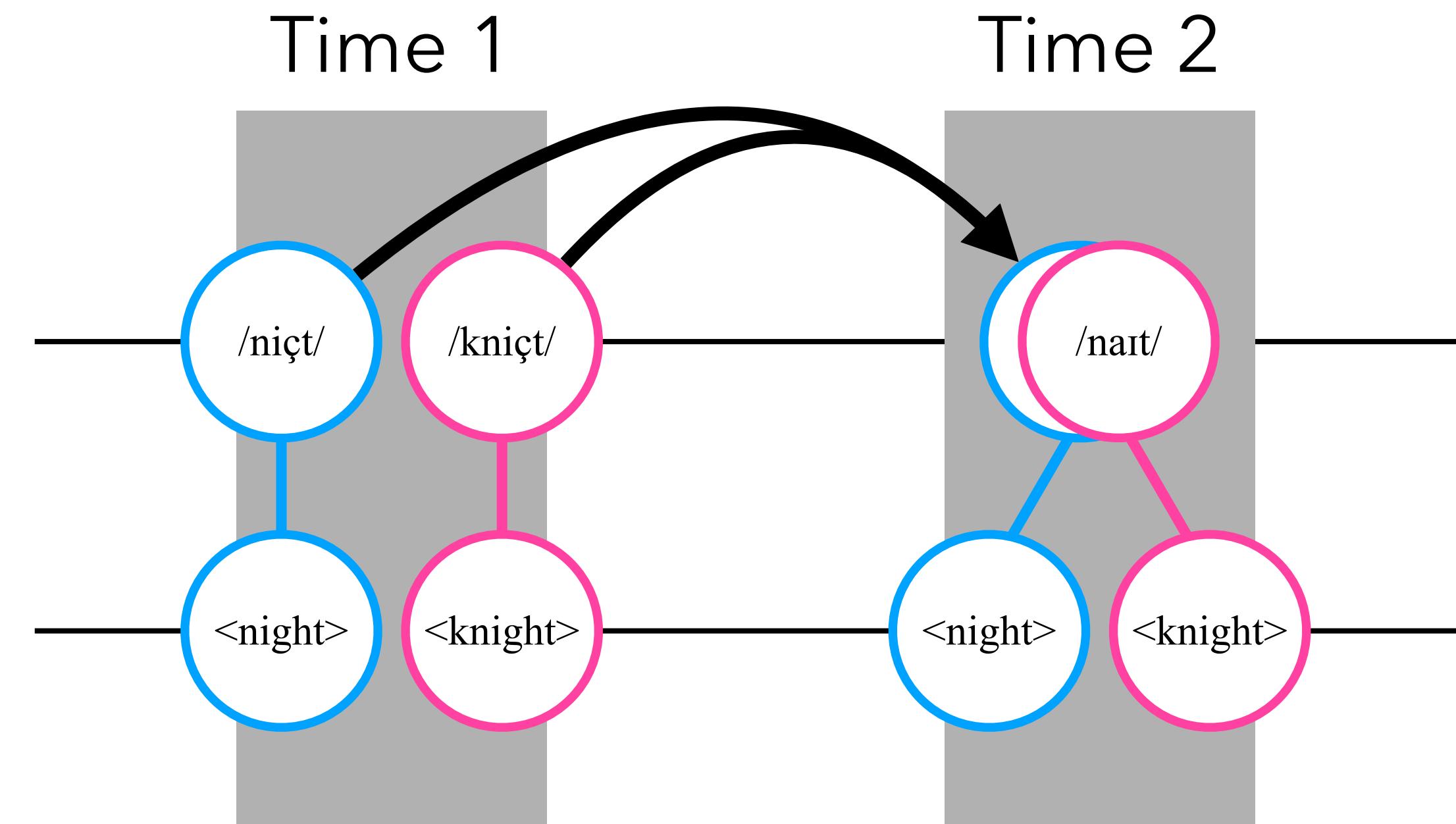
1. We test the idea that heterography emerges in response to a functional pressure to disambiguate meaning in writing.

- 1.** We test the idea that heterography emerges in response to a functional pressure to disambiguate meaning in writing.
- 2.** We seek to understand how the emergence of heterography plays out under the two mechanisms of differentiation and conservation.

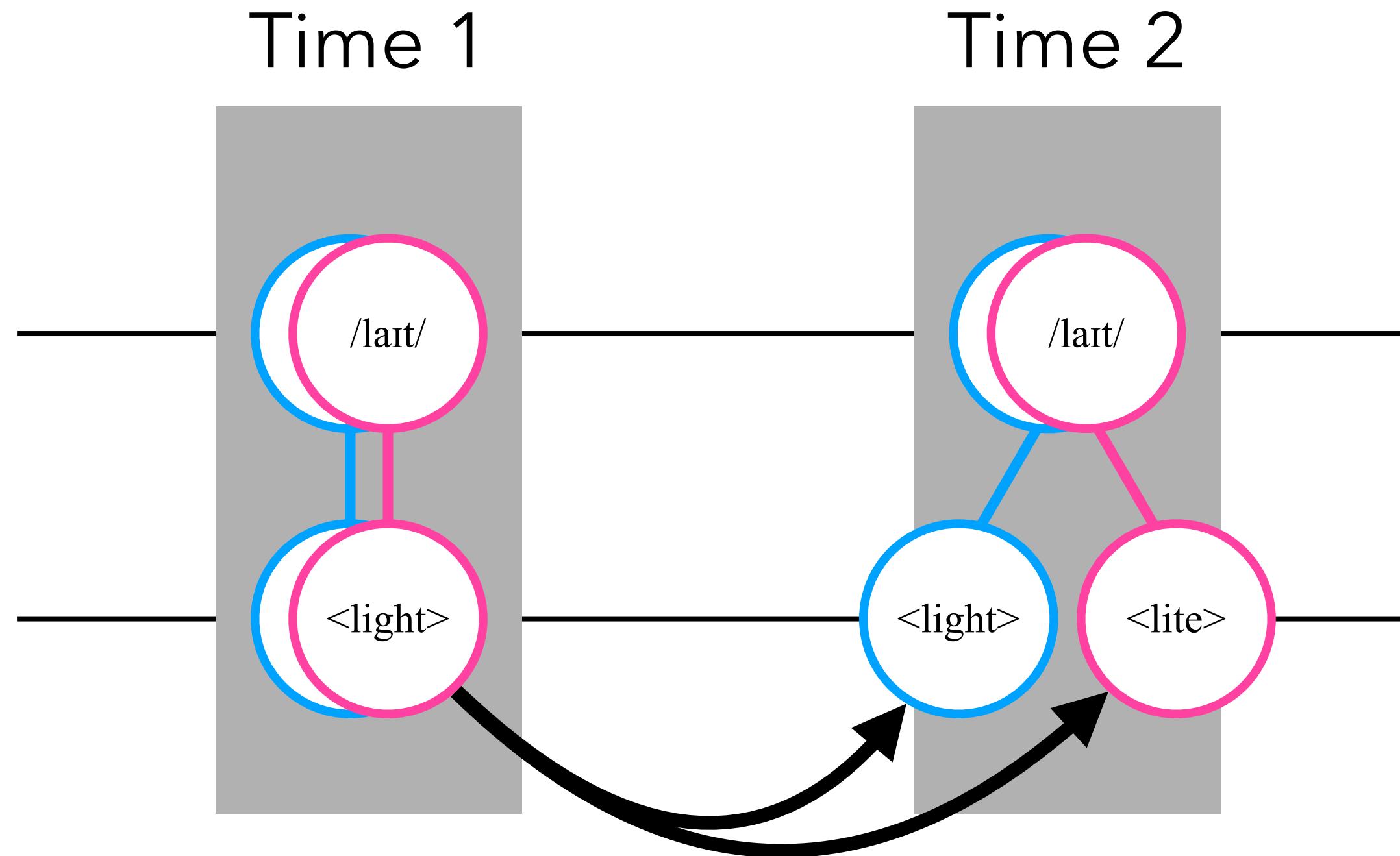
Differentiation



Conservation

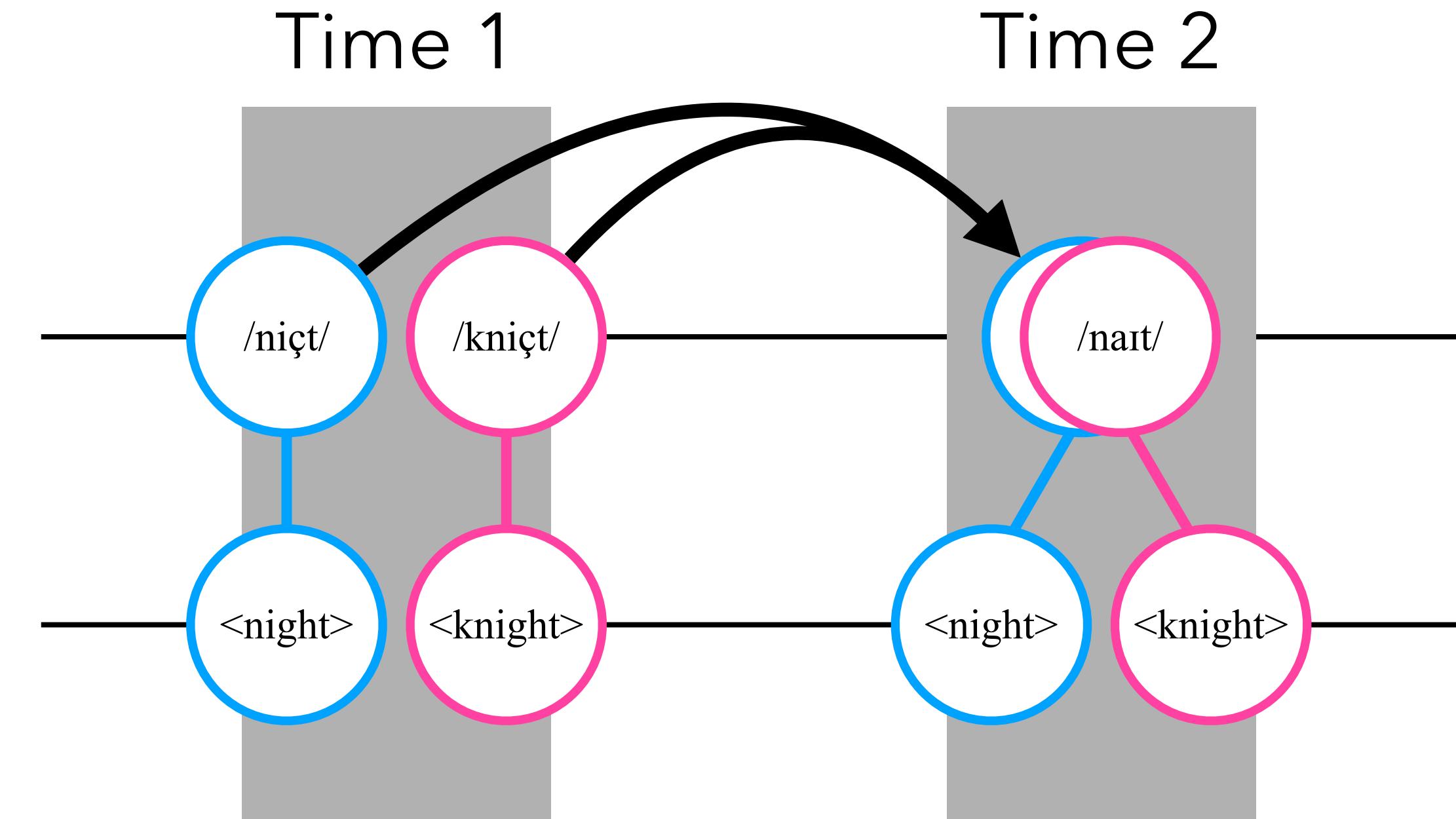


Differentiation



*light-lite, bite-byte, check-cheque
by-bye, for-fore, or-ore, be-bee, in-inn, to-too, but-but
Carr, Wilde; Blu-Tack, Wite-Out
discreet-discrete, flower-flour, plain-plane*

Conservation



*heal-heel, leak-leek, meat-meet, read-reed, sea-see, team-teem, weak-week
/kn/ → /n/: knight-night, know-no, knot-not
/ç/ → /Ø/: eight-ate, right-rite, sight-site
/m/ → /w/: whale-wail, which-witch, whine-wine*

- 1.** We test the idea that heterography emerges in response to a functional pressure to disambiguate meaning in writing.
- 2.** We seek to understand how the emergence of heterography plays out under the two mechanisms of differentiation and conservation.

- 1.** We test the idea that heterography emerges in response to a functional pressure to disambiguate meaning in writing.
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↑
Experiment 1

↑
Experiment 2

Two conditions: evolution **with** and **without** communicative pressure

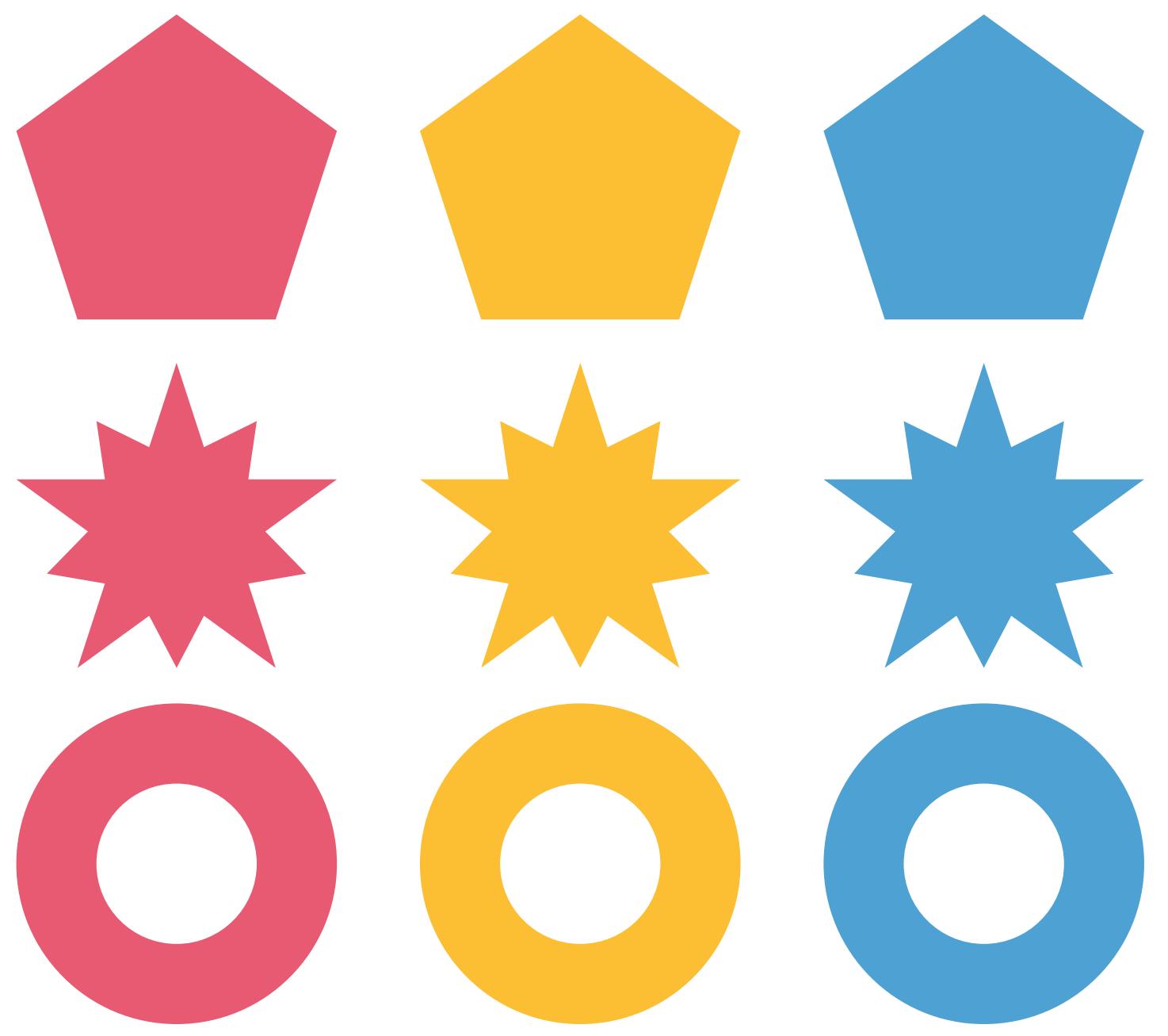
1. We test the idea that heterography emerges in response to a functional pressure to disambiguate meaning in writing.
2. We seek to understand how the emergence of heterography plays out under the two mechanisms of differentiation and conservation.

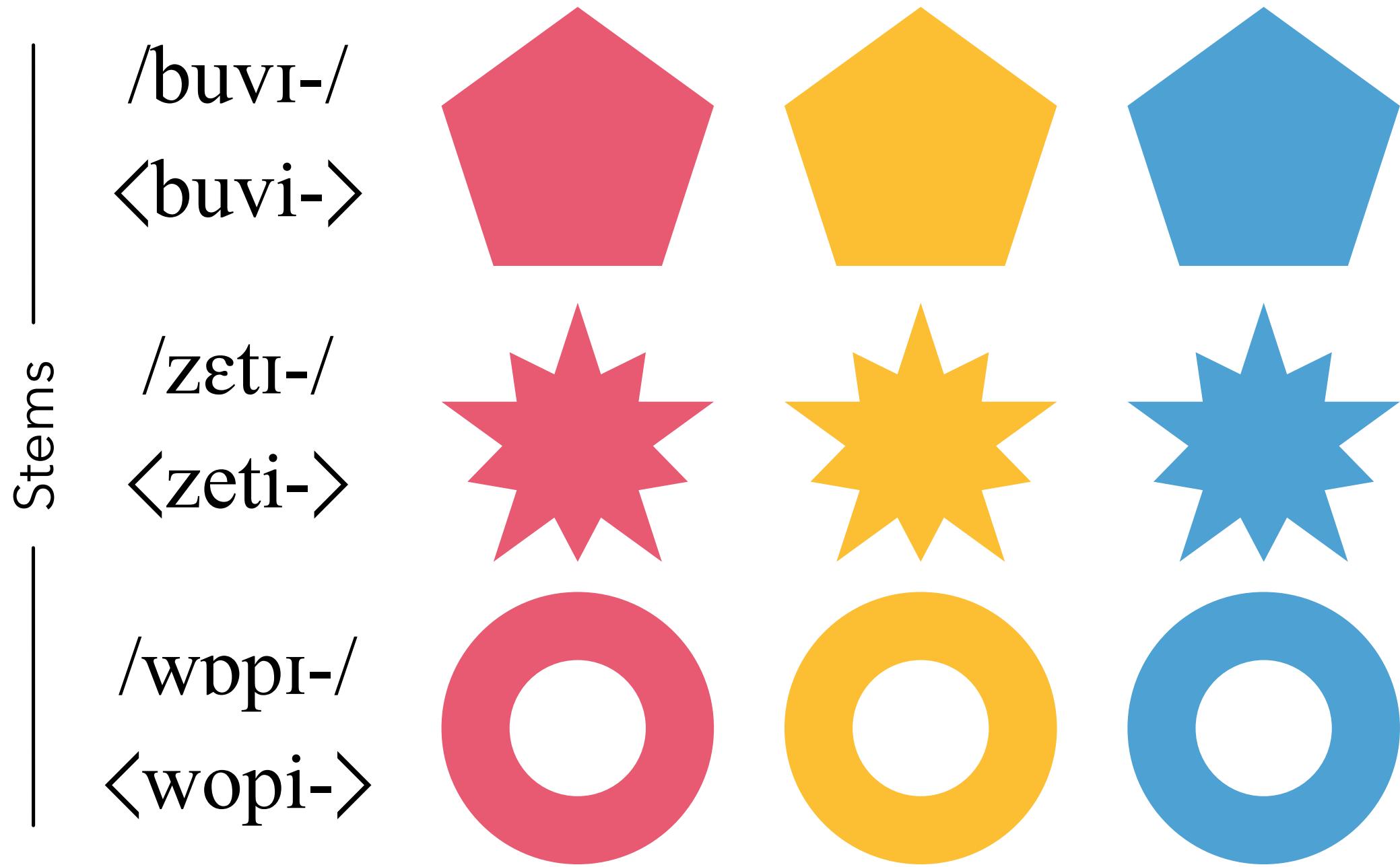
Experiment 1

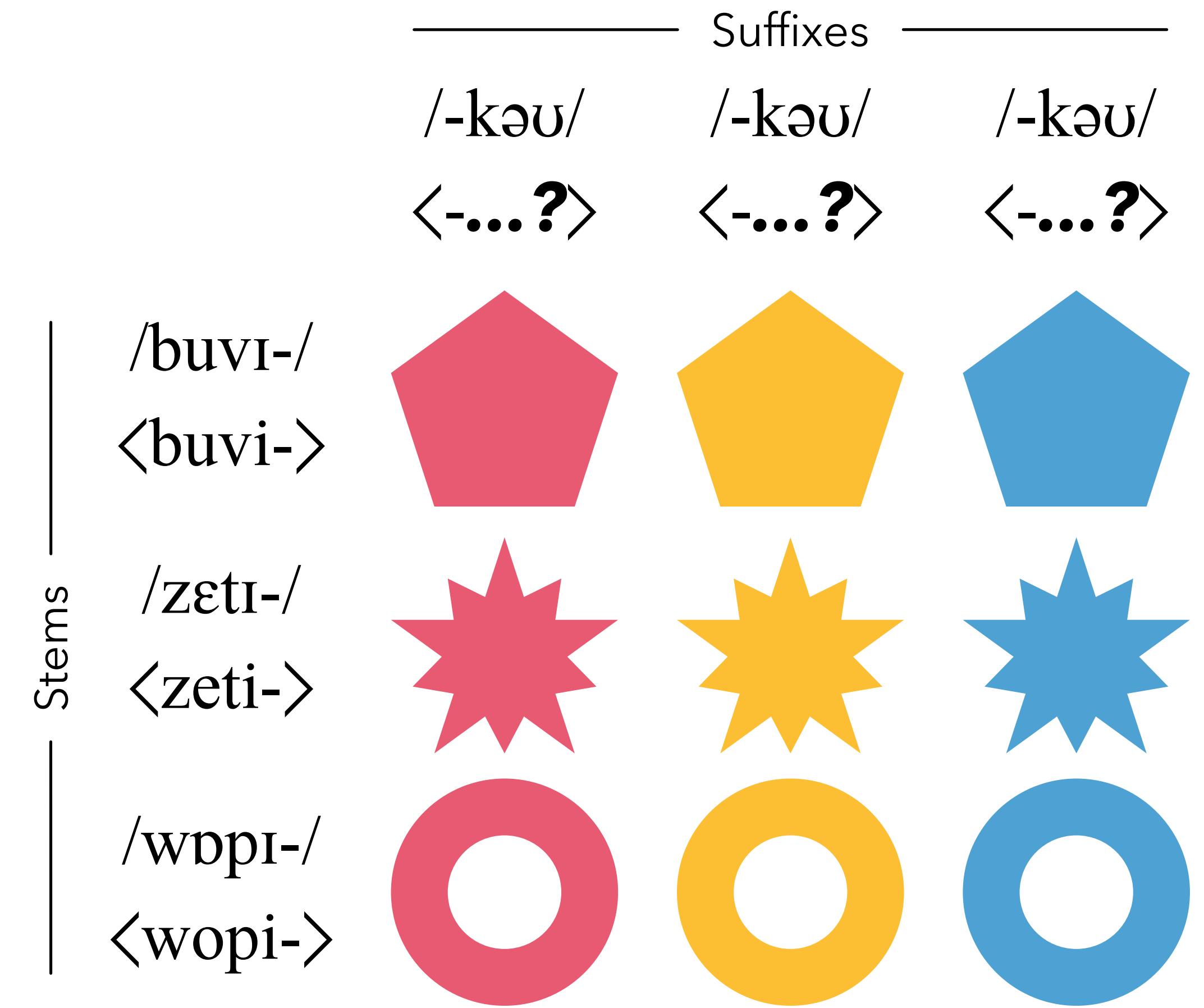
Experiment 2

Experiment 1:

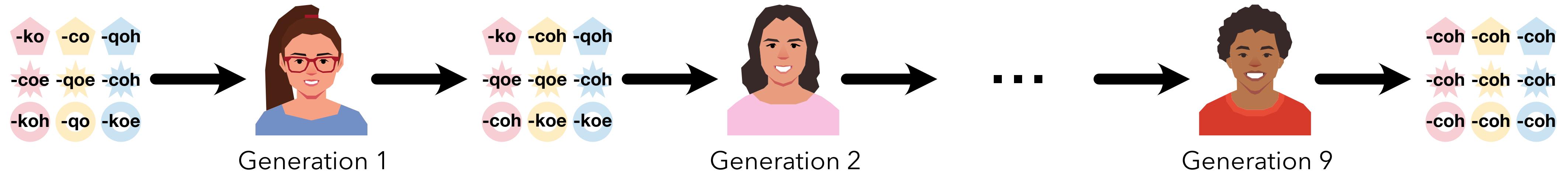
Differentiation



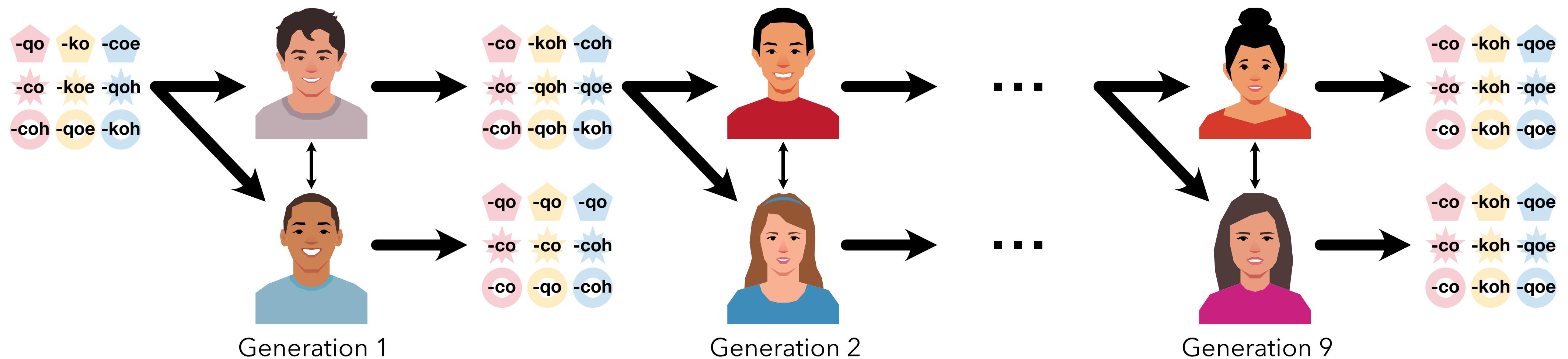


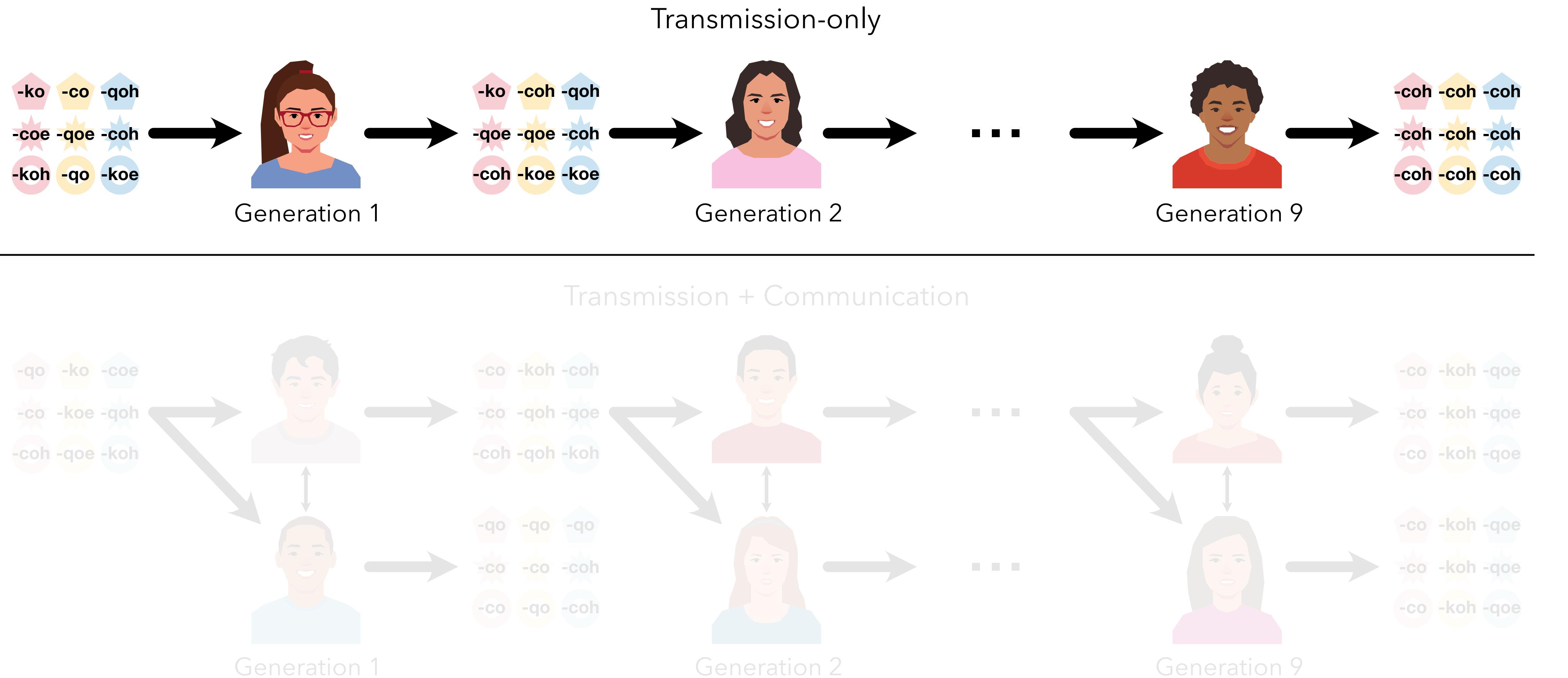


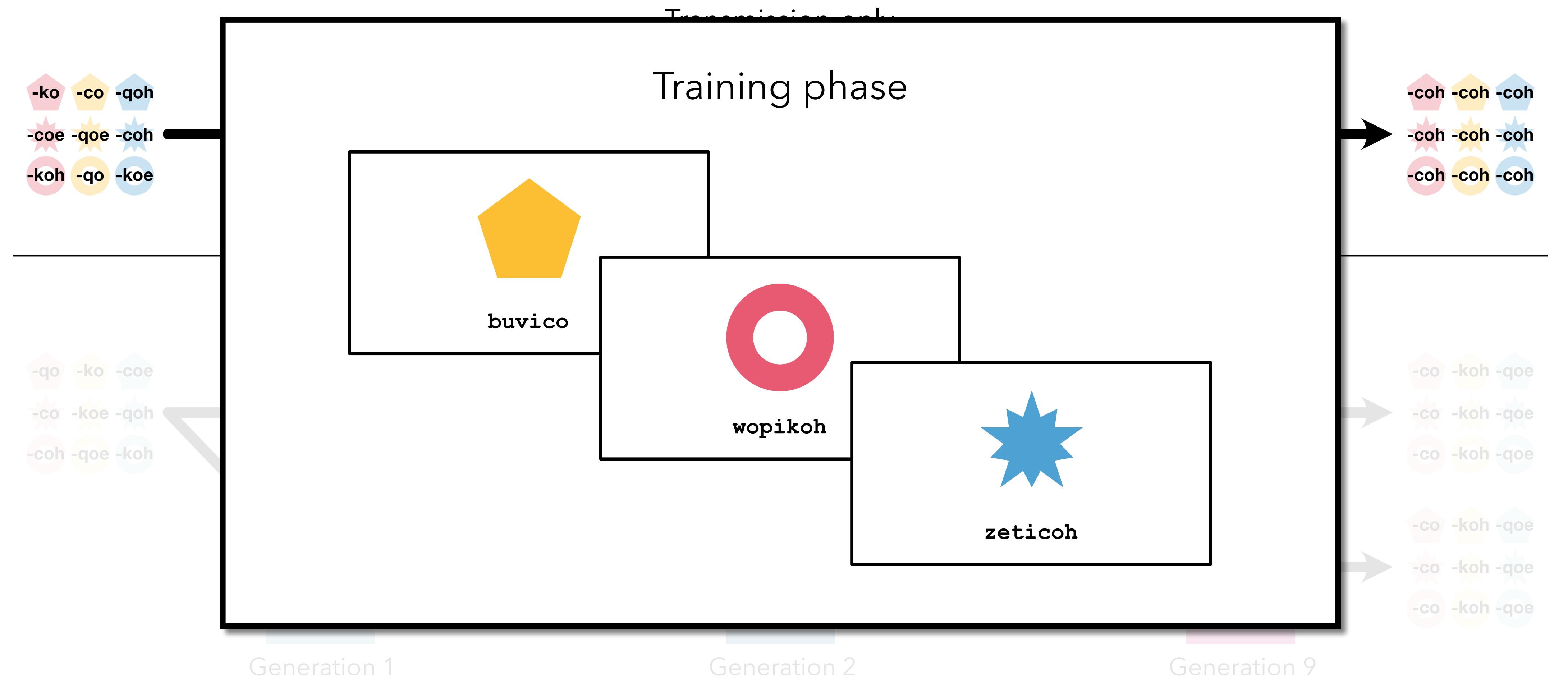
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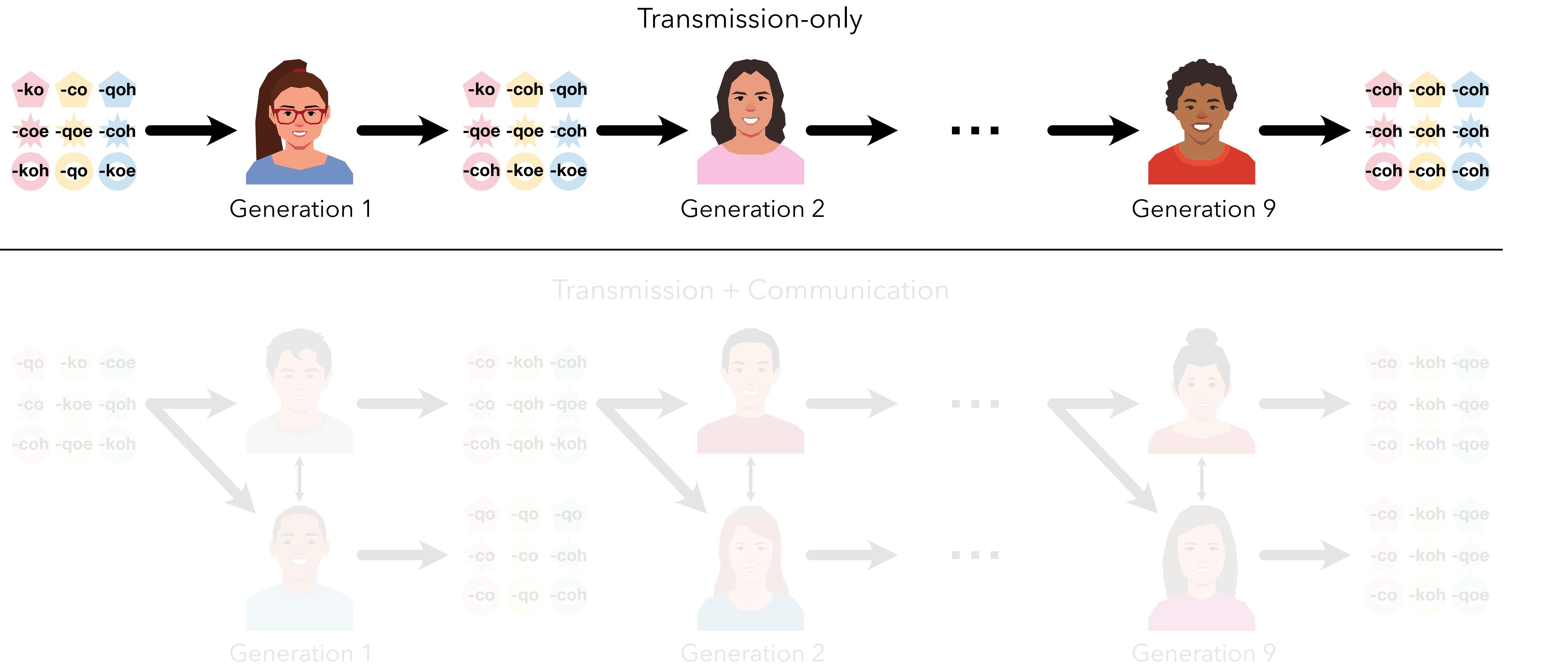


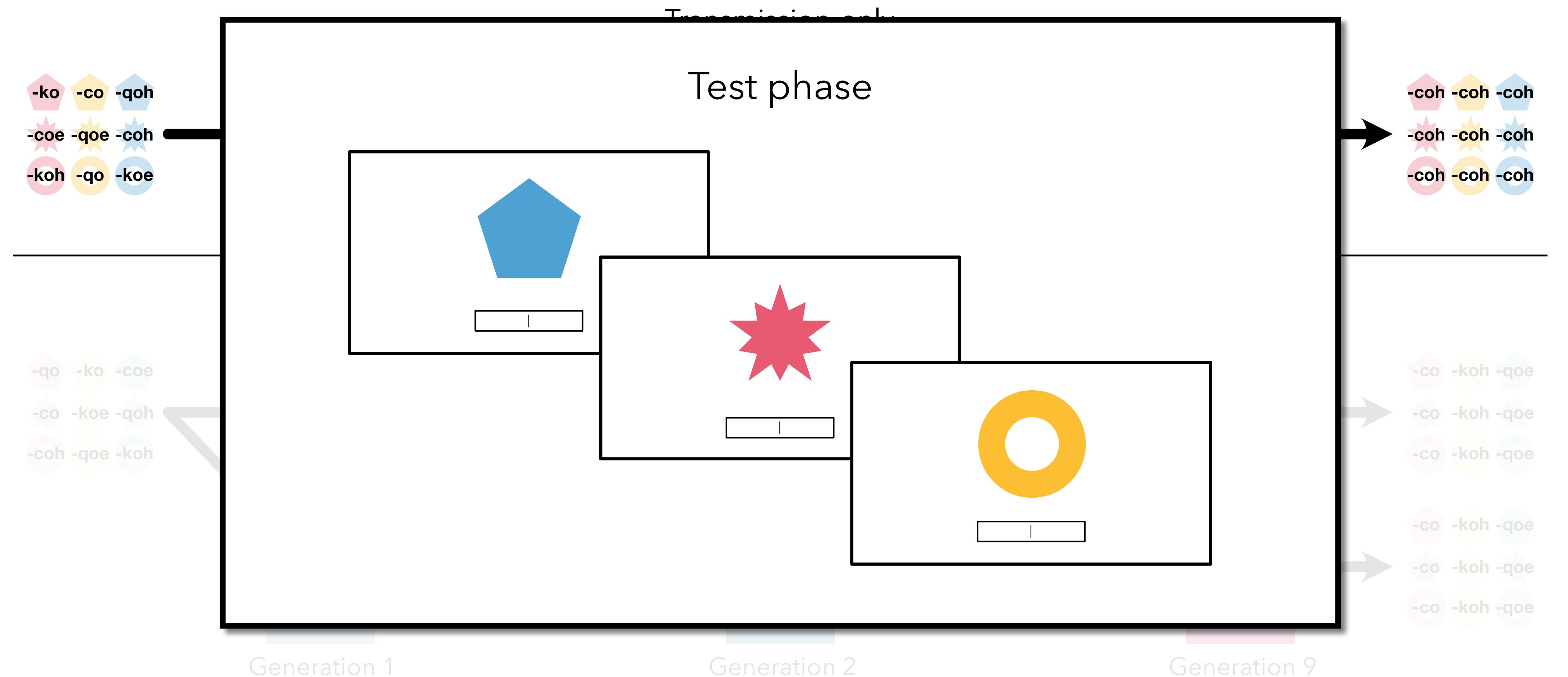
Transmission + Communication

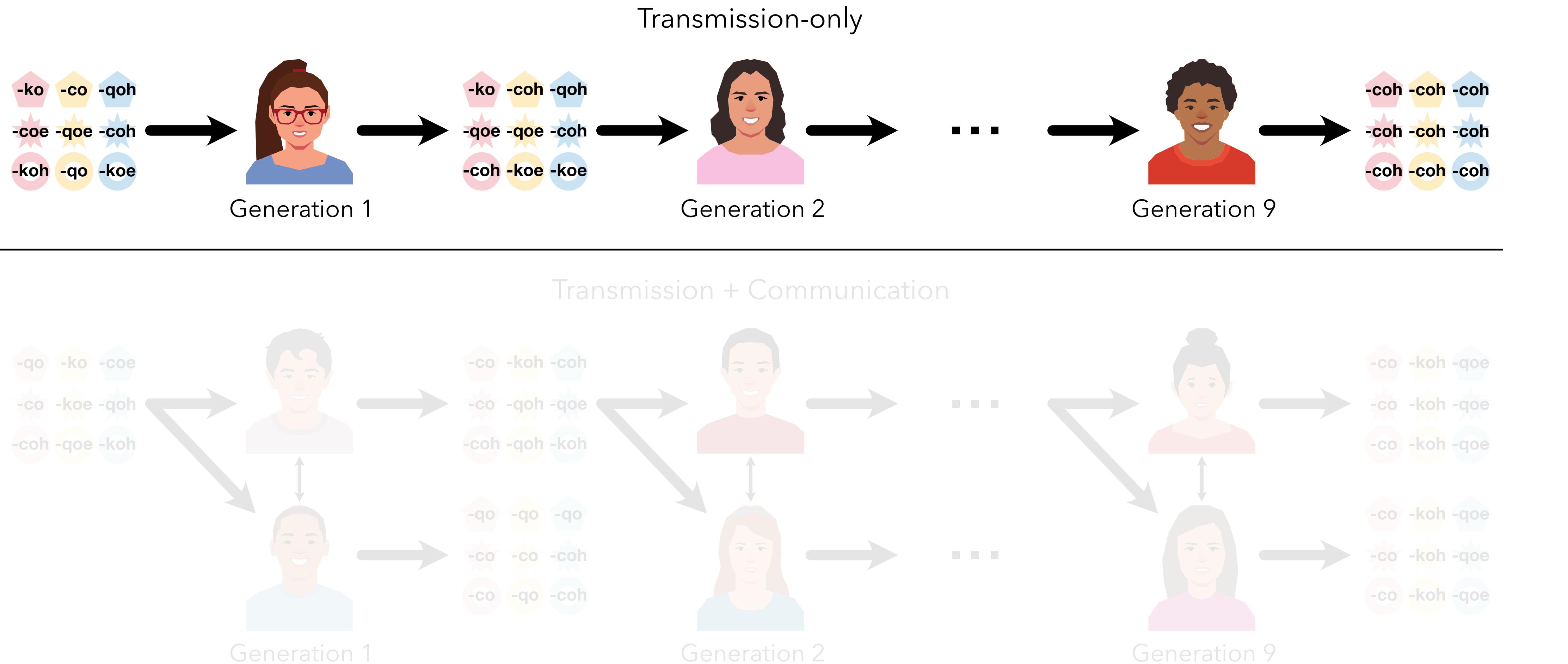




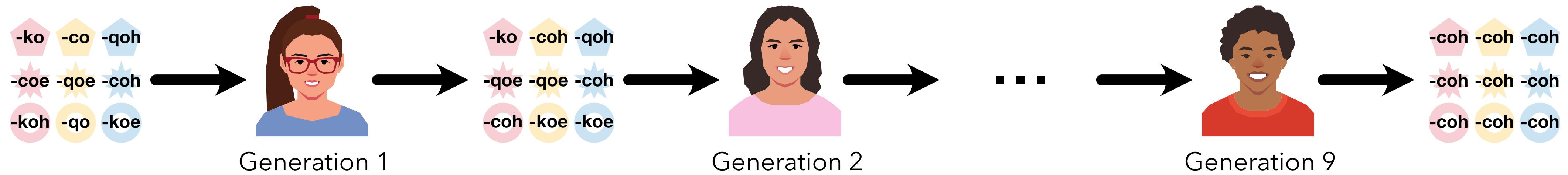




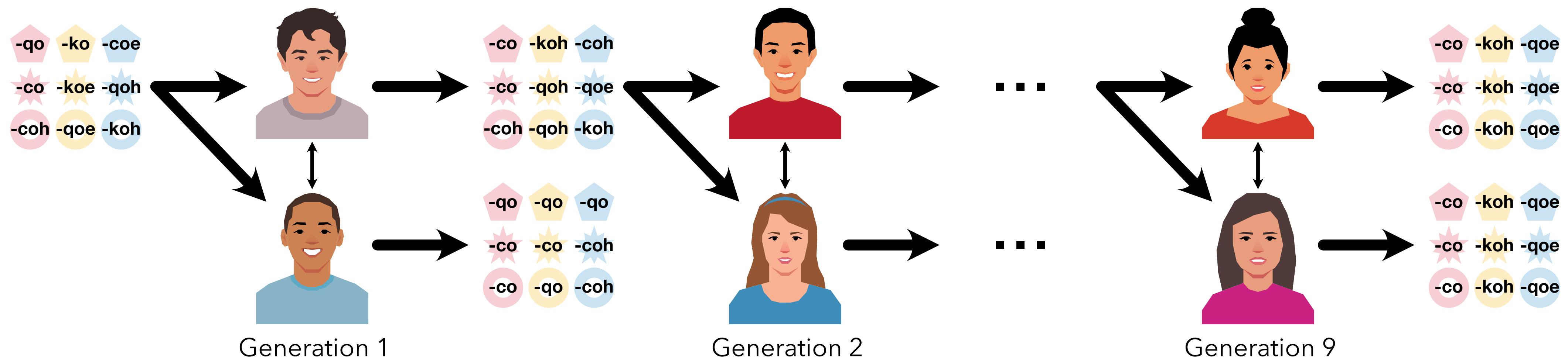


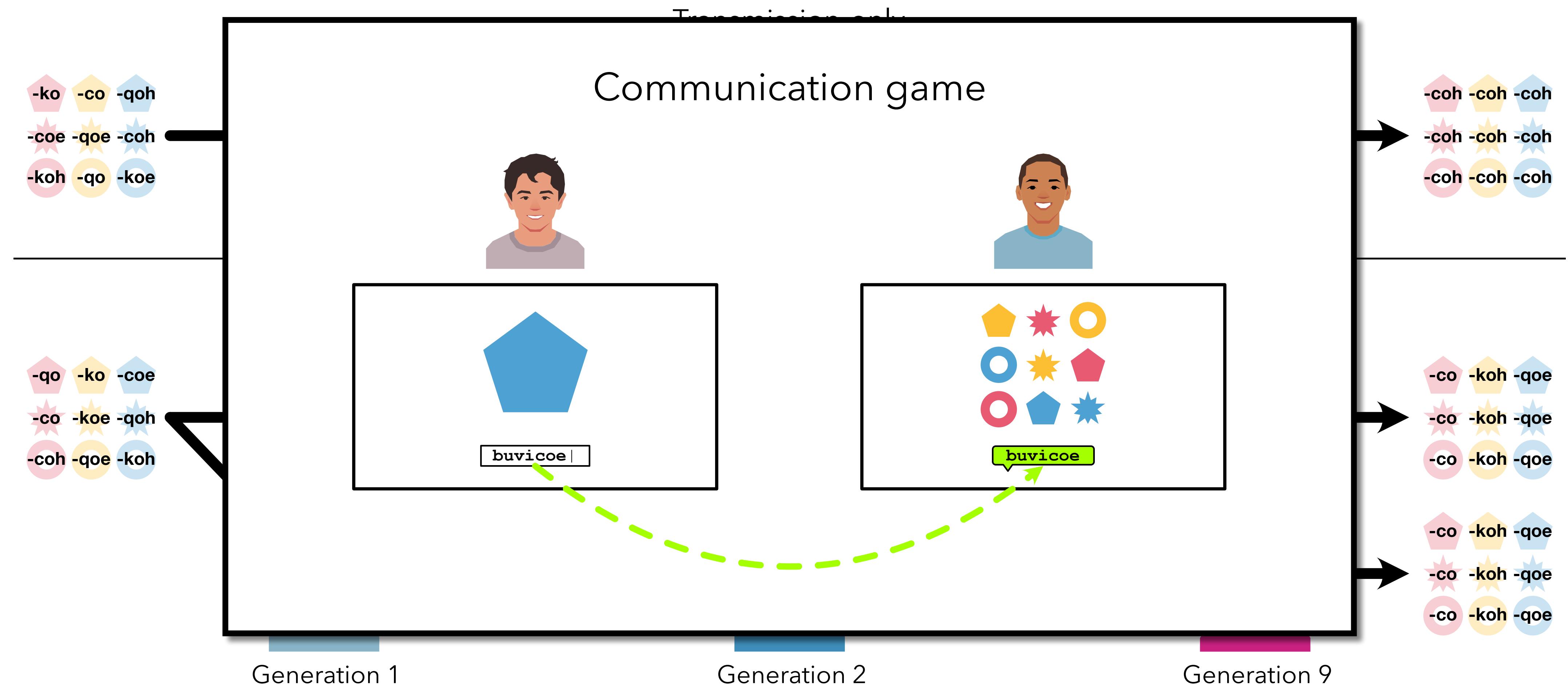


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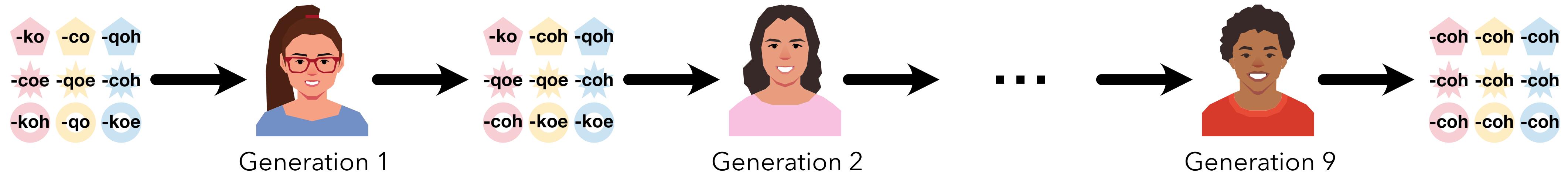


Transmission + Communication

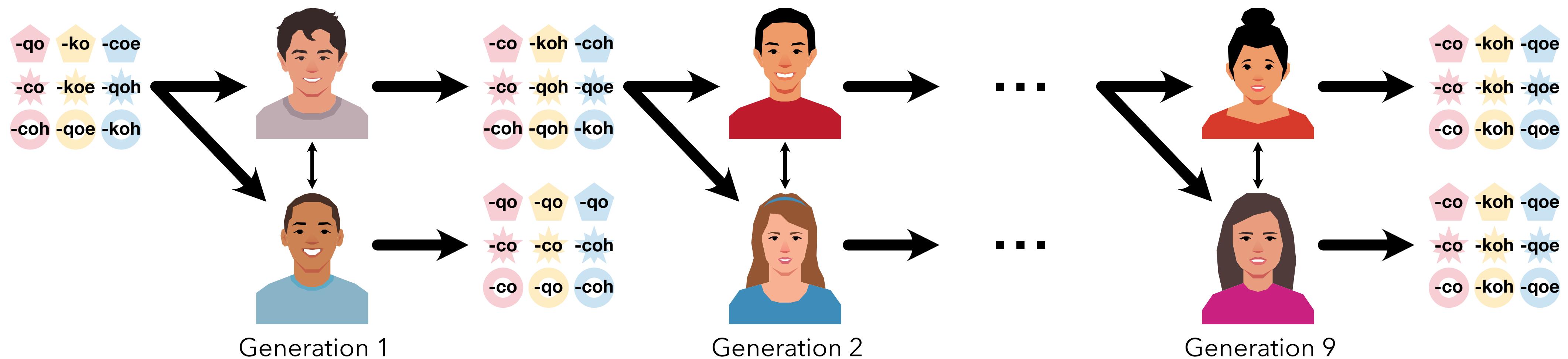




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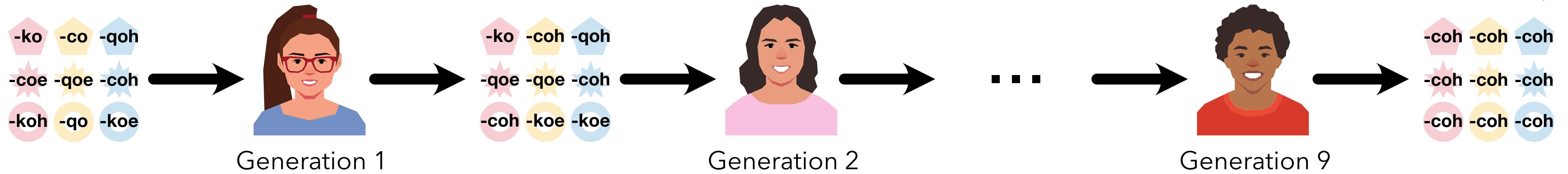


Transmission + Communication



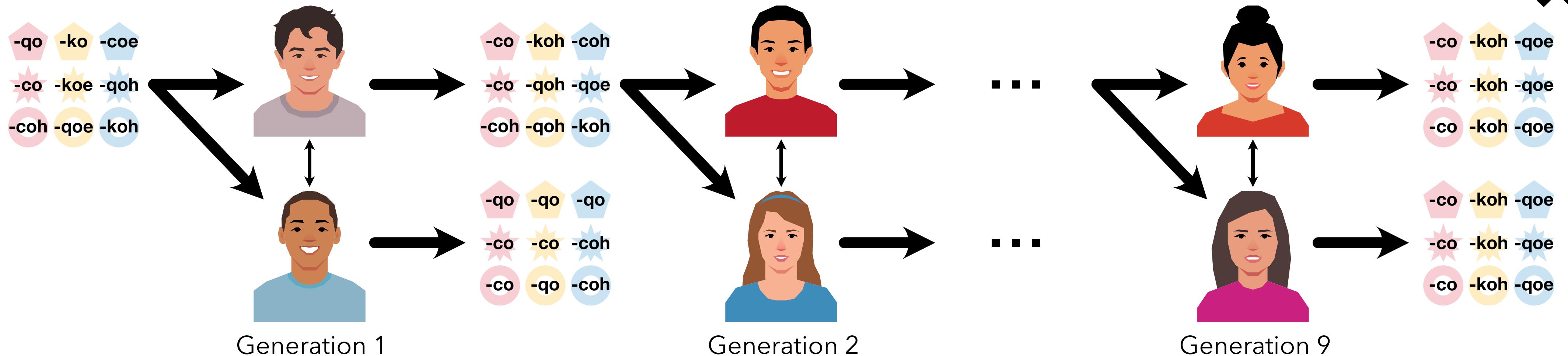
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Transmission-only



×10

Transmission + Communication



Transmission-only

0 1 2 3 4 5 6 7 8 9

A

ko	co	qoh
coe	qoe	coh
koh	qo	koe

ko	coh	qoh
qoe	qoe	coh
coh	ko	koe

coh	coh	coh
qoe	co	coh
coh	coh	coh

coh	coh	coh
qoe	co	coh
coh	coh	coh

coh	coh	coh
qoe	co	coh
coh	coh	coh

coh	coh	coh
qoe	co	coh
coh	coh	coh

coh	coh	coh
qoe	co	coh
coh	coh	coh

B

koh	qoe	coh
koe	co	coh
co	qoh	ko

coh	coh	coh
co	co	co
co	co	co

coh	coh	coh
co	co	co
co	co	co

coh	coh	coh
co	co	co
co	co	co

coh	coh	coh
co	co	co
co	co	co

C

qoe	co	coh
qoh	koe	koh
go	ko	co

aoe	co	co
qoh	koh	koh
ko	ko	ko

coe	co	co
koh	koh	koh
ko	ko	ko

coe	co	co
koh	koh	koh
ko	ko	ko

coe	co	co
koh	koh	koh
ko	ko	ko

D

goe	koe	qoh
co	ko	koh
coh	qo	coe

koe	koe	qoh
koe	ko	koe
coh	co	coh

koe	koe	qoh
koh	ko	ko
coh	co	co

koe	koe	qoh
ko	ko	ko
co	co	co

koe	koe	qoh
ko	ko	ko
co	co	co

E

qoe	co	qo
ko	co	qoh
koh	co	ko

qoe	qu	qo
co	co	co
ko	qu	qu

qu	qu	qu
co	co	co
ko	qu	qu

qu	qu	qu
co	co	co
ko	qu	qu

qu	qu	qu
co	co	co
ko	qu	qu

F

coe	qo	qoe
coh	koh	qoh
koe	co	ko

qoe	qoe	qoe
qoh	koh	qoh
ko	qoh	qoh

qoe	qoe	qoh
qoh	qoh	qoh
ko	qoh	qoh

qoe	qoe	qoh
qoh	qoh	qoh
ko	qoh	qoh

qoe	qoe	qoh
qoh	qoh	qoh
ko	qoh	qoh

G

koe	koh	qoh
que	coh	coe
go	co	ko

koh	koh	koh
coh	co	co
co	co	co

co	co	co
co	co	co
co	co	co

co	co	co
co	co	co
co	co	co

co	co	co
co	co	co
co	co	co

H

qoh	qoe	ko
qoh	koh	ko
coe	koh	co

qoh	koh	ko
qoh	qoh	qoh
ko	qoh	qoh

ko	ko	ko
qoh	qoh	qoh
ko	ko	ko

ko	ko	ko
qoh	qoh	qoh
ko	ko	ko

ko	ko	ko
qoh	qoh	qoh
ko	ko	ko

I

coe	co	koh
coh	co	co
koh	co	co

coe	co	co
coe	co	co
coe	co	co

coe	co	co
coe	co	co
coe	co	co

coe	co	co
coe	co	co
coe	co	co

coe	co	co
coe	co	co
coe	co	co

J

qoh	co	co
koh	co	co
koh	qoe	co

koh	qoe	co
koh	ko	co
koh	qoe	co

koh	ko	co
koh	ko	co
koh	ko	co

koh	ko	co
koh	ko	co
koh	ko	co

koh	ko	co
koh	ko	co
koh	ko	co

Transmission + Communication

0 1 2 3 4 5 6 7 8 9

K

coe	ko	qoe
qoh	koh	coh
ko	co	co

coe	co	co
qoh	qoe	qoh
ko	qoh	qoh

co	co	co
co	co	co
co	co	co

co	co	co
co	co	co
co	co	co

co	co	co
co	co	co
co	co	co

L

koh	coe	ko
qu	qoe	co
co	qoh	ko

co	coe	co
ko	qoh	ko
q	c	q

co	co	co
co	co	co
c	co	q

co	co	co
co	co	co
co	co	co

co	co	co
co	co	co
co	co	co

M

qoe	co	ko
qoh	ko	koh
co	qo	qoh

coe	co	co
koe	ko	koh
coe	ko	koh

coe	ko	co
koe	koh	koh
coe	koh	koh

coe	ko	co
koe	koh	koh
coe	koh	koh

coe	ko	co
koe	koh	koh
coe	koh	koh

N

coh	ko	qoe
ko	qo	qoh
ko	ko	ko

ko	ko	ko
ko	ko	ko
ko	ko	ko

ko	ko	ko
ko	ko	ko
ko	ko	ko

ko	ko	ko
ko	ko	ko
ko	ko	ko

ko	ko	ko
ko	ko	ko
ko	ko	ko

O

coe	ko	ko
qoh	qoe	ko
ko	ko	ko

co	ko	ko
koe	ko	ko
ko	ko	ko

co	ko	ko
koe	ko	ko
ko	ko	ko

co	ko	ko
koe	ko	ko
ko	ko	ko

co	ko	ko
koe	ko	ko
ko	ko	ko

P

co	co	co
qoh	co	qoh
co	co	co

co	co	co
qoh	co	qoh
co	co	co

co	co	co
qoh	co	qoh
co	co	co

co	co	co
qoh	co	qoh
co	co	co

co	co	co
qoh	co	qoh
co	co	co

Q

coh	co	co
ko	qo	ko
co	co	co

co	co	co
ko	qo	ko
co	co	co

co	co	co
ko	qo	ko
co	co	co

co	co	co
ko	qo	ko
co	co	co

co	co	co
ko	qo	ko
co	co	co

R

Transmission-only

coe	co	koh
coh	qoe	qo
ko	koe	qoh

coe	koh	coh
coe	coh	coe
ko	coe	qoh

koh	koh	koh
coe	coe	coe
ko	coe	qoh

koh	koh	koh
coe	coe	coe
co	co	co

koh	coe	co
co	co	co
co	co	co

coe	co	co
co	co	co
co	co	co

coe	co	co
co	co	co
co	co	co

coe	co	co
co	co	co
co	co	co

coe	co	co
co	co	co
co	co	co

coe	co	co
co	co	co
co	co	co

coe	co	co
co	co	co
co	co	co

coe	co	co
co	co	co
co	co	co

Transmission + Communication

coe	koe	qoe
qoh	koh	coh
ko	co	qo

koe	co	koe
qoh	qoe	qoh
ko	co	co

koe	co	koe
qoh	qoh	qoh
ko	co	co

koe	koe	co
ko	quo	quo
co	co	co

ko	ko	co
ko	quo	ko
co	co	co

ko	ko	co
ko	co	co
co	co	co

ko	qo	co
ko	co	co
co	ko	co

qo	co	qo
co	ko	ko
co	co	co

qo	co	co
co	ko	ko
co	co	co

qo	co	co
co	co	co
co	co	co

qo	co	co
co	co	co
co	co	co

qo	co	co
co	co	co
co	co	co

qo	co	co
co	co	co
co	co	co

qo	co	co
co	co	co
co	co	co

qo	co	co
co	co	co
co	co	co

qo	co	co
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co	co	co

qo	co	co
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qo	co	co
co	co	co
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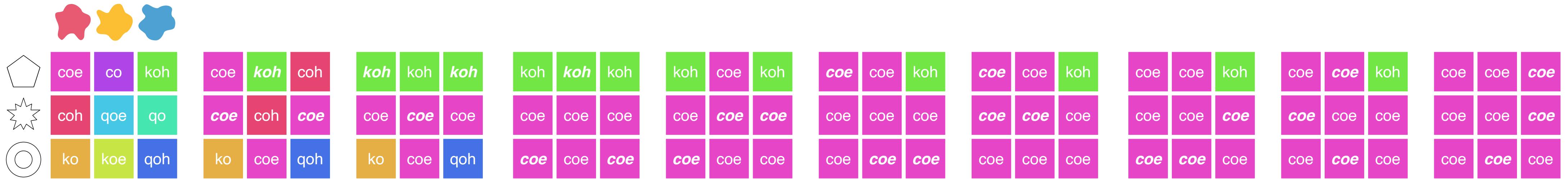
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co	co	co
co	co	co

qo	co	co
co	co	co
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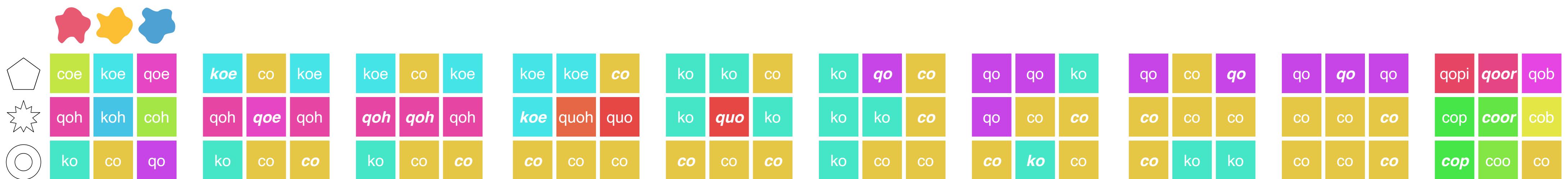
qo	co	co

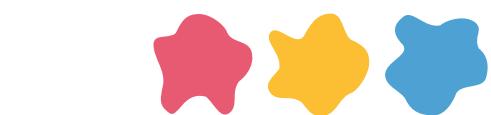
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Transmission-only



Transmission + Communication





	coe	co	koh
	coh	qoe	qo
	ko	koe	qoh

↑
Holistic

Transmission-only

	coe	koh	coh
	coe	coh	coe
	ko	coe	qoh

	koh	koh	koh
	coe	coe	coe
	ko	coe	qoh

	koh	koh	koh
	coe	coe	coe
	co	coe	coe

	koh	coe	koh
	coe	coe	coe
	co	coe	coe

	coe	coe	koh
	coe	coe	coe
	co	coe	coe

	coe	coe	coe
	coe	coe	coe
	co	coe	coe

Transmission + Communication



	coe	koe	qoe
	qoh	koh	coh
	ko	co	qo

	koe	co	koe
	qoh	qoe	qoh
	ko	co	co

	koe	co	koe
	qoh	qoh	qoh
	ko	co	co

	koe	quoh	quo
	ko	quo	ko
	co	co	co

	ko	ko	co
	ko	ko	co
	co	co	co

	ko	co	co
	ko	co	co
	co	co	co

	ko	co	co
	ko	co	co
	co	co	co

Transmission-only



	coe	co	koh
	coh	qoe	qo
	ko	koe	qoh
	coe	koh	coh
	coe	coh	coe
	ko	coe	qoh

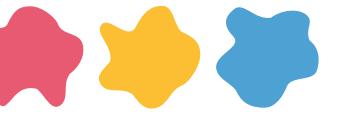
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	coe	coe	coe
	ko	coe	qoh
	koh	koh	koh
	coe	coe	coe
	ko	coe	qoh

	koh	coe	koh
	coe	coe	coe
	ko	coe	qoh
	koh	coe	koh
	coe	coe	coe
	ko	coe	qoh

	coe	coe	koh
	coe	coe	coe
	coe	coe	coe
	coe	coe	koh
	coe	coe	coe
	coe	coe	coe

	coe	coe	coe
	coe	coe	coe
	coe	coe	coe
	coe	coe	coe
	coe	coe	coe
	coe	coe	coe

Transmission + Communication



	coe	koe	qoe
	qoh	koh	coh
	ko	co	qo
	koe	co	koe
	qoh	qoe	qoh
	ko	co	co

	koe	co	koe
	qoh	qoe	qoh
	ko	co	co
	koe	co	koe
	qoh	qoh	qoh
	ko	co	co

	ko	co	co
	ko	co	co
	ko	co	co
	ko	co	co
	co	co	co
	ko	co	co

	ko	ko	co
	ko	ko	co
	ko	ko	co
	ko	ko	co
	co	ko	co
	ko	ko	co

	qo	co	qo
	co	co	co
	co	co	co
	qo	co	qo
	co	co	co
	co	co	co

	qo	qo	qo
	co	co	co
	co	co	co
	qo	qo	qo
	co	co	co
	co	co	co

Transmission-only



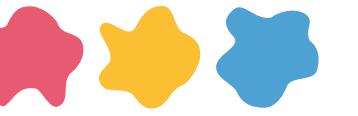
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	coh	qoe	qo	coe	coh	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe
	ko	koe	qoh	ko	coe	qoh	ko	coe	qoh	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe	coe

↑ Holistic

↑ Redundant

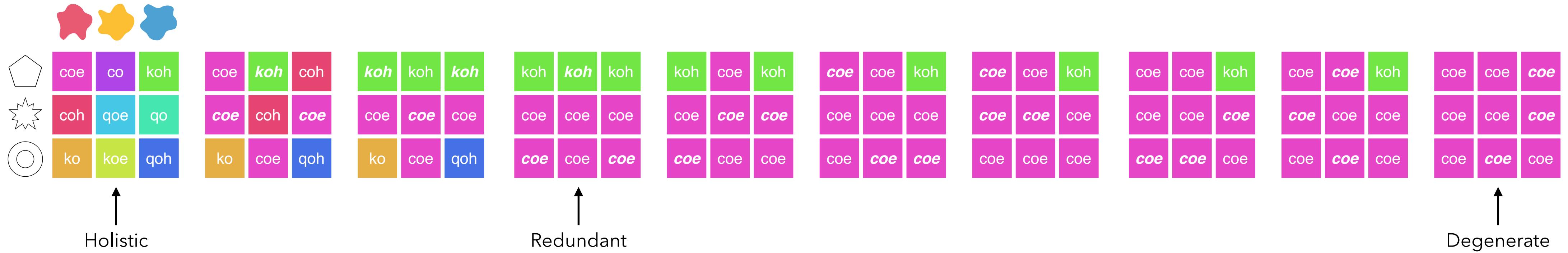
↑ Degenerate

Transmission + Communication

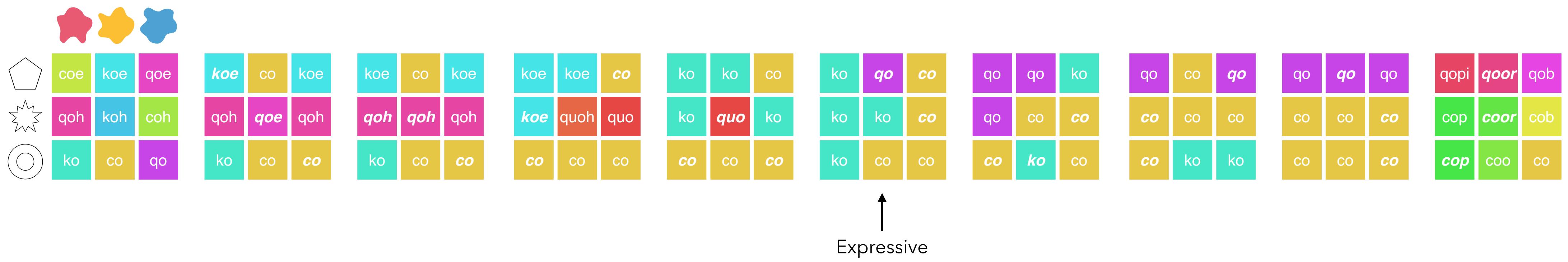


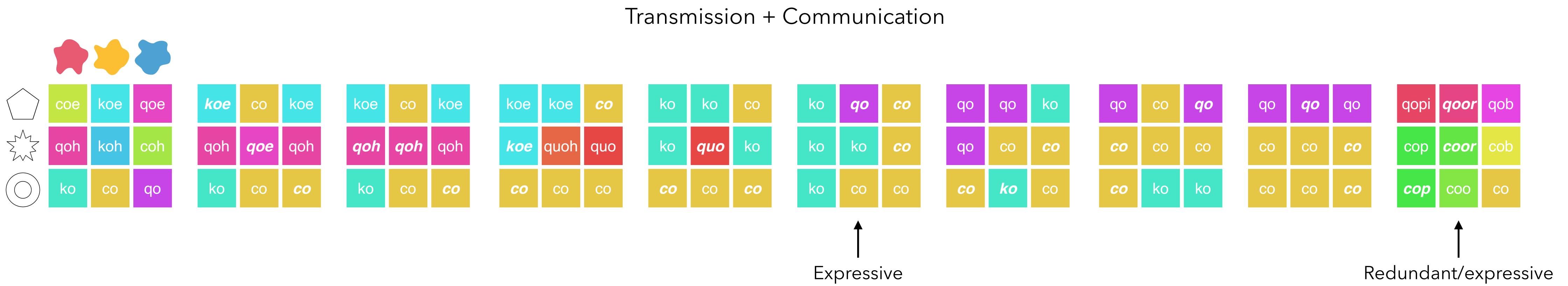
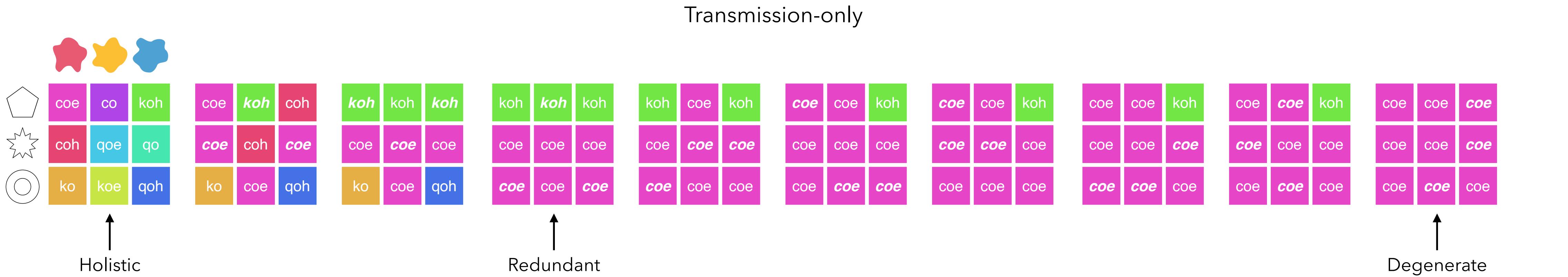
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	qoh	koh	coh	qoh	qoe	qoh	qoh	qoh	qoh	qoh	co	quoh	quo	ko	quo	ko	co	co	qo	co	qo	co	co	co
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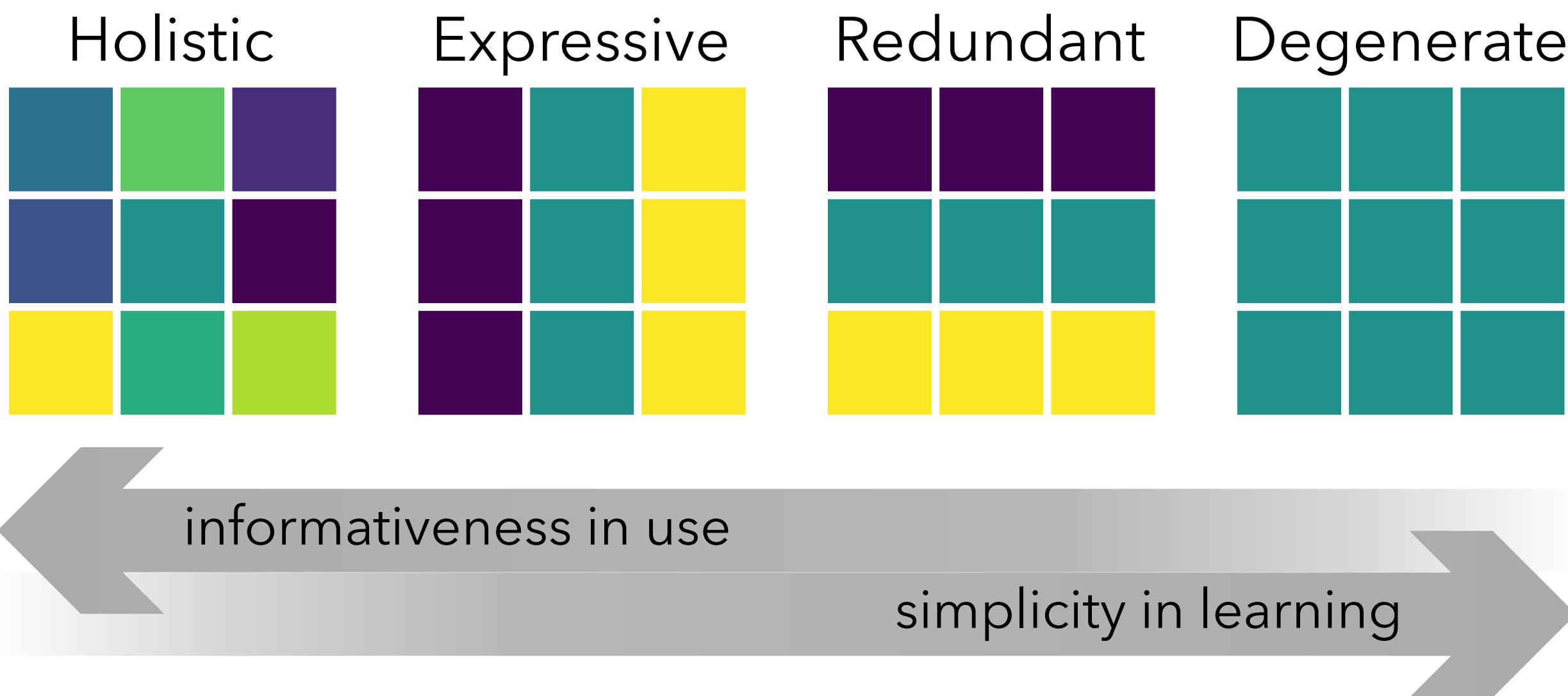
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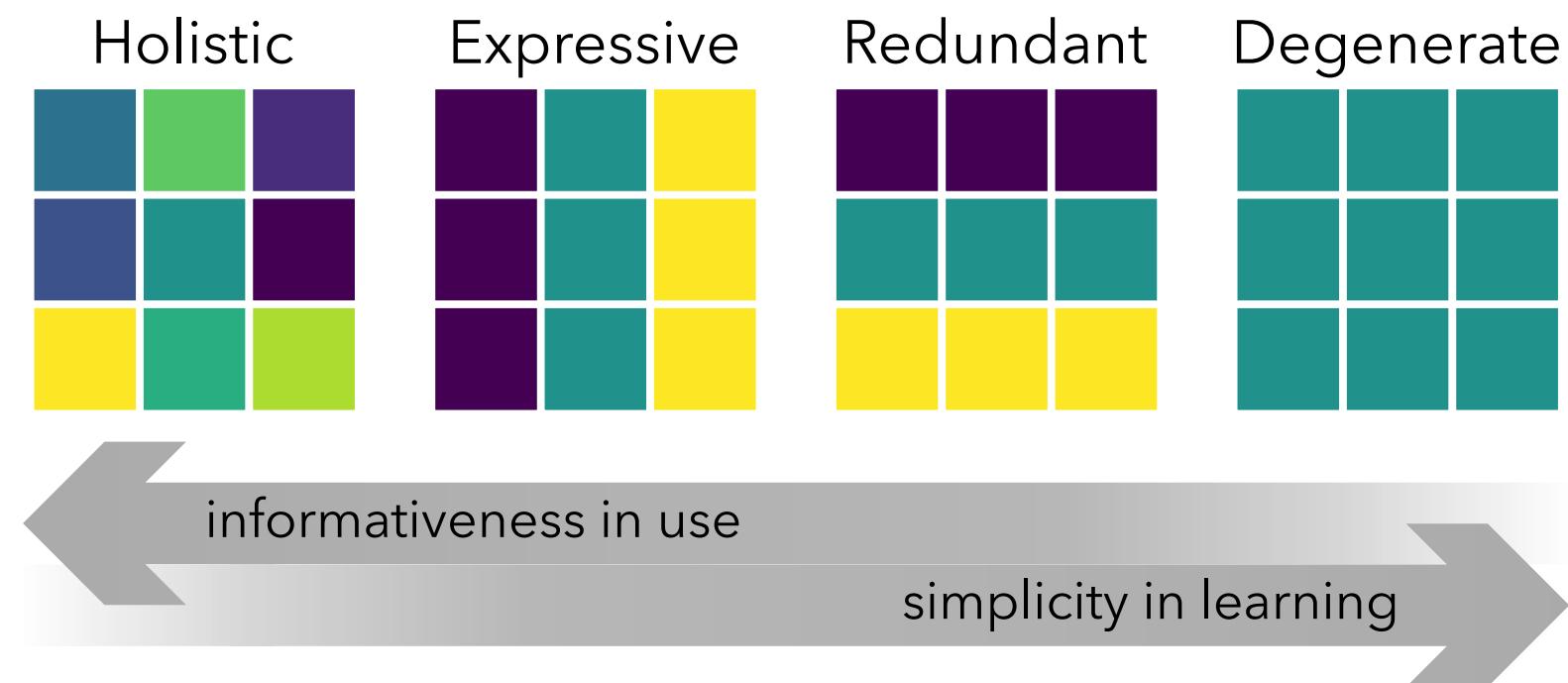
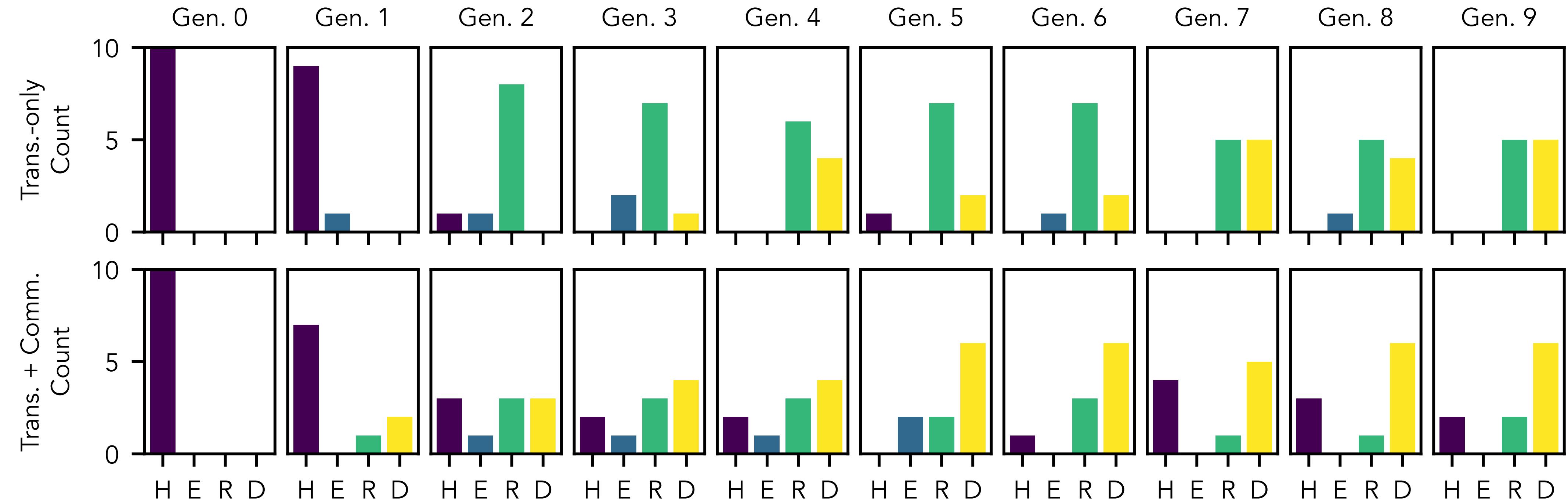


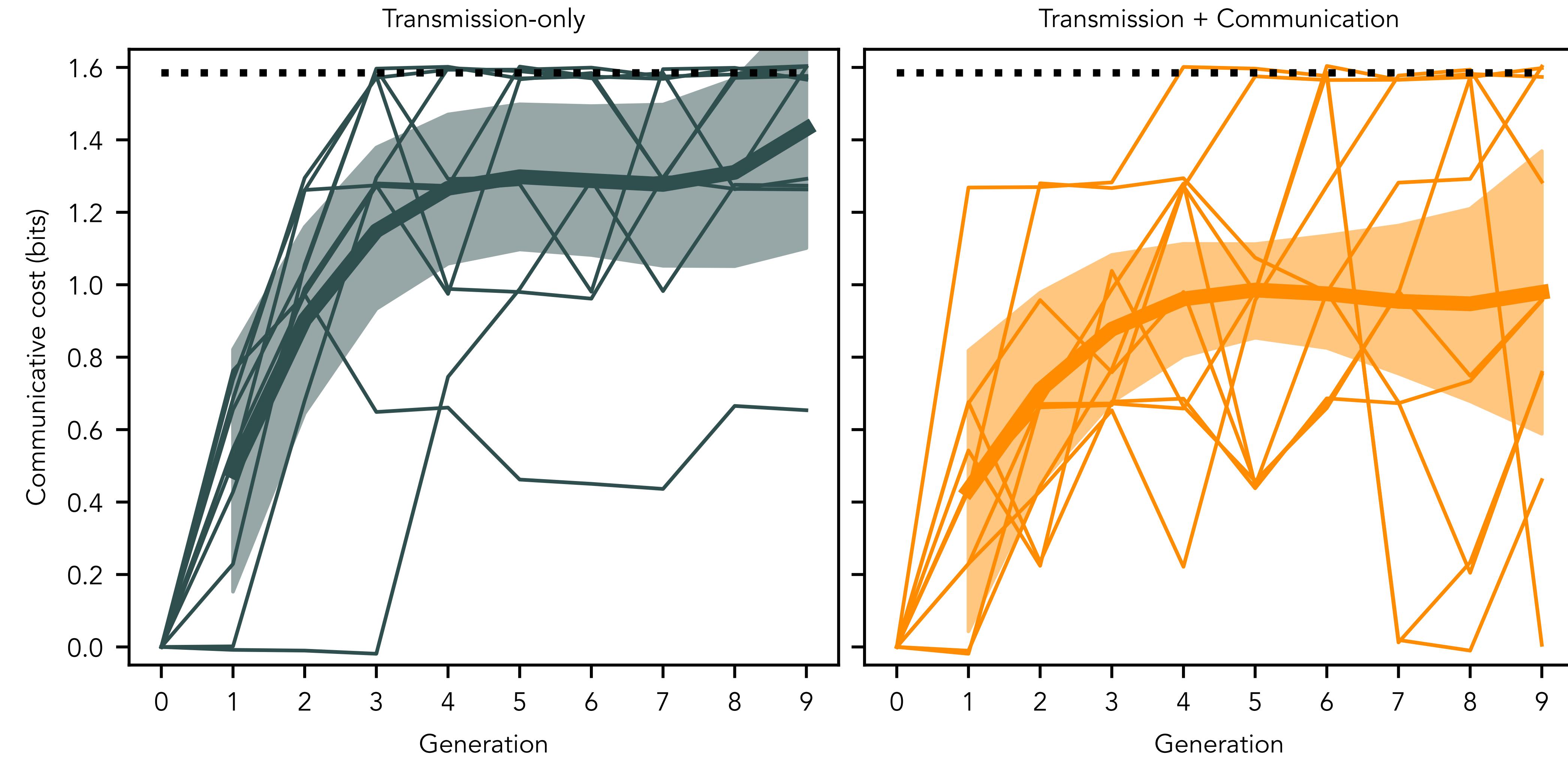
Transmission + Communication







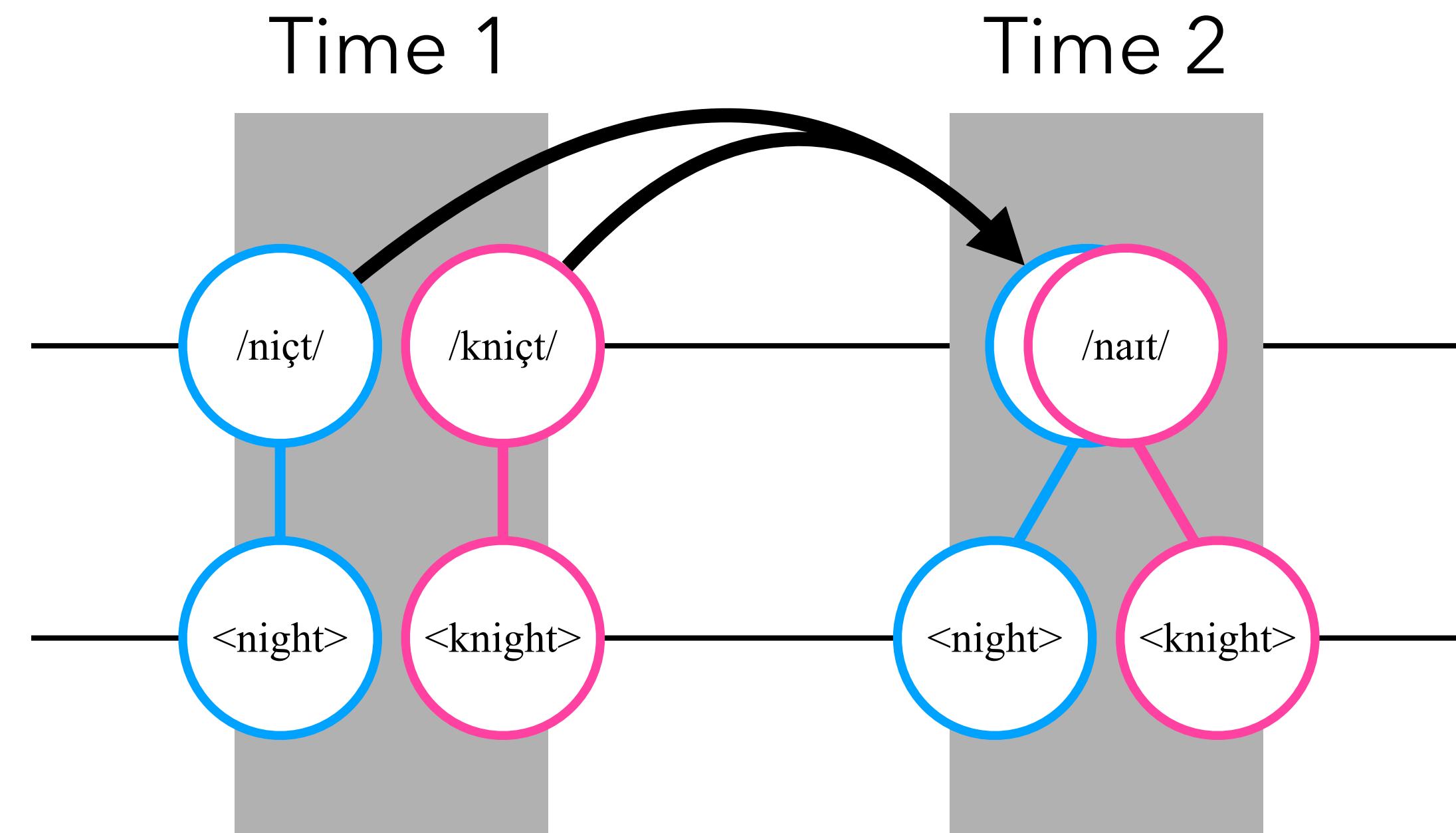


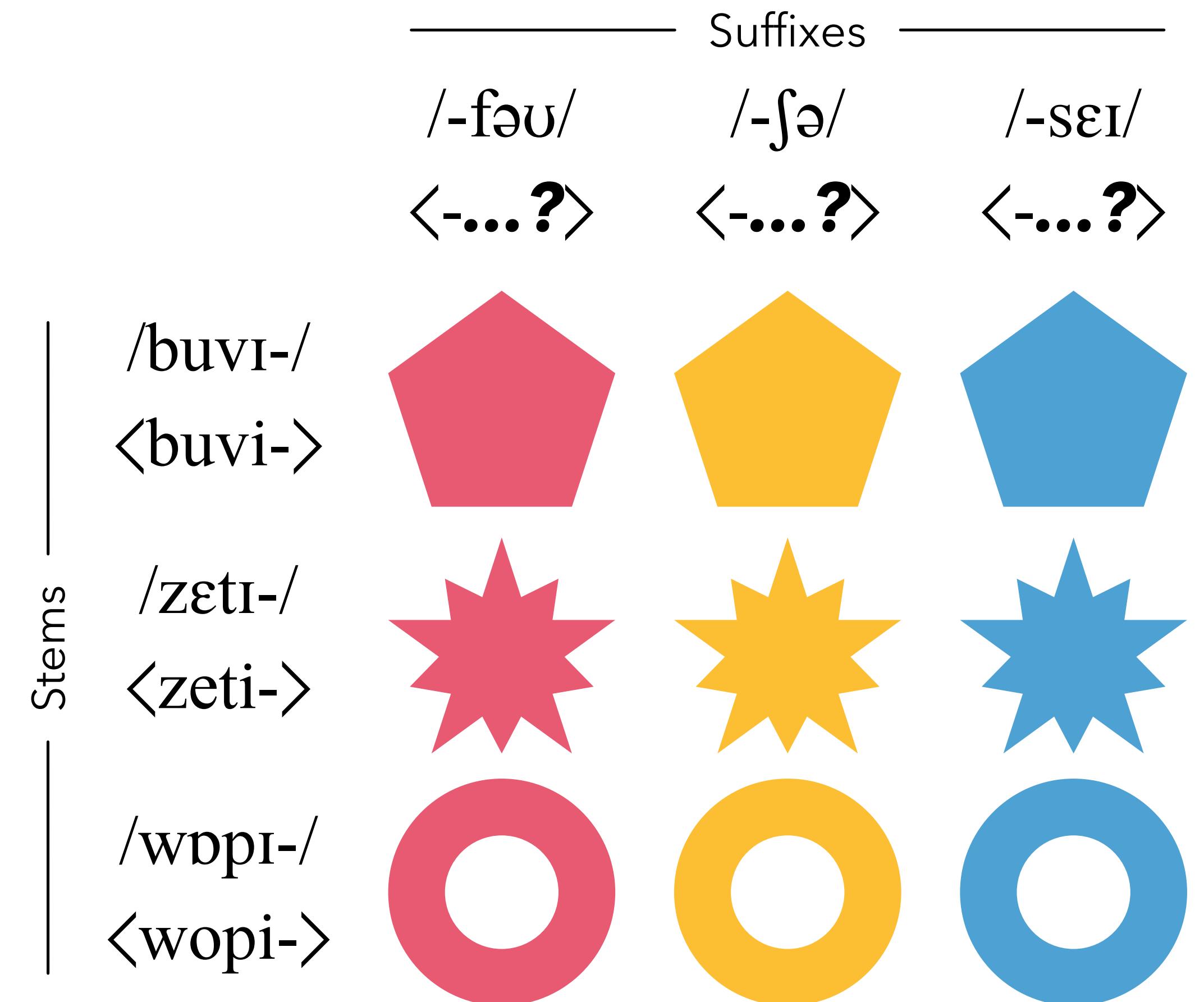


Experiment 2:

Conservation

Conservation





Epoch I
Generations 1-3

Epoch II
Generations 4-6

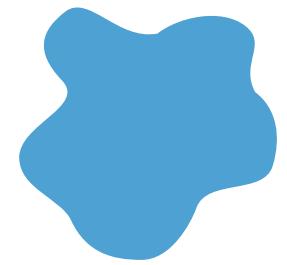
Epoch III
Generations 7-9



/-fəʊ/ → /-fɛɪ/ → /-fə/



/-ʃə/ → /-ʃə/ → /-fə/



/-sɛɪ/ → /-fɛɪ/ → /-fə/

Sound change 1

/s/ → /f/, /əʊ/ → /ɛɪ/

Sound change 2

/ʃ/ → /f/, /ɛɪ/ → /ə/

Transmission-only

Transmission + Communication

	0	1	2	3	4	5	6	7	8	9
K	soe fa xei	soe fa xei	soe fa xei	soe fa xei	soe fa feix	soe fei fei	soe fei fei	fei fei fei	fei fei fei	fei fei fei
L	fa soe xei	fa soe xei	fa soe xei	fa soe xei	so fa fei	so fey fei	so fei fei	fei fei fei	fei fei fei	fei fei fei
M	fa soe xei	fa soe xei	soe fa xei	soe fa xei	fa so fa	fa so fa	fa so fa	fa sol fa	fa fa fa	fa sol fa
N	soe fa xei	soe fa xei	soe fa xei	soe fa xei	soe fei fei	soe fei fei	soe fei fei	soe fei fei	soe zie soe	soe zie soe
O	sa foe xei	sa foe xei	sa foe xei	sa foe xei	sa soe xie	soe fei fei	soe fei fei	soe zie soe	fie fie soe	fie fie soe
P	fa xoe sei	fa xoe sei	fa xoe sei	fa xoe sei	fa xoe sei	fa xoe sei	fa xoe sei	fa xoe sei	soe soe soe	soe soe soe
Q	xa fei soe	sha fe soe	sha fa soe	fa fa soe	fa fa soe					
R	xa fei soe	sha fe soe	sha fay soe	sha fay soe	sha fa soe	sha fa soe	sha fa soe	sha fa soe	sha fa soe	sha fa soe
S	soe xei fa	soe shei fa								
T	fei sa xoe	fei sa xoe	fei sa xoe	fei sa xoe	fei sa xo	fei sa xo	fei sa xo	fei fe so	fe fe so	fe fe fe

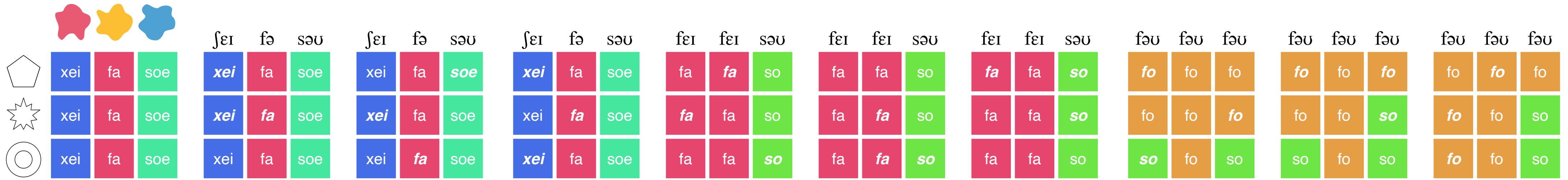
Transmission-only

<i>xei</i>	fa	soe	<i>ʃei</i>	fe	səu	<i>ʃei</i>	fe	səu	<i>ʃei</i>	fe	səu	<i>fəi</i>	<i>fəi</i>	səu	<i>fəi</i>	<i>fəi</i>	səu	<i>fəi</i>	<i>fəi</i>	səu	<i>fəu</i>	<i>fəu</i>	<i>fəu</i>	<i>fəu</i>	<i>fəu</i>	<i>fəu</i>	
<i>xei</i>	fa	soe	<i>fa</i>	<i>fa</i>	so	<i>fa</i>	<i>fa</i>	so	<i>fa</i>	<i>fa</i>	so	<i>fo</i>	<i>fo</i>	<i>fo</i>	<i>fo</i>	<i>fo</i>	<i>fo</i>										
<i>xei</i>	fa	soe	<i>fa</i>	<i>fa</i>	<i>so</i>	<i>fa</i>	<i>fa</i>	<i>so</i>	<i>fa</i>	<i>fa</i>	<i>so</i>	<i>so</i>	<i>fo</i>	<i>fo</i>	<i>so</i>	<i>so</i>	<i>fo</i>	<i>so</i>									

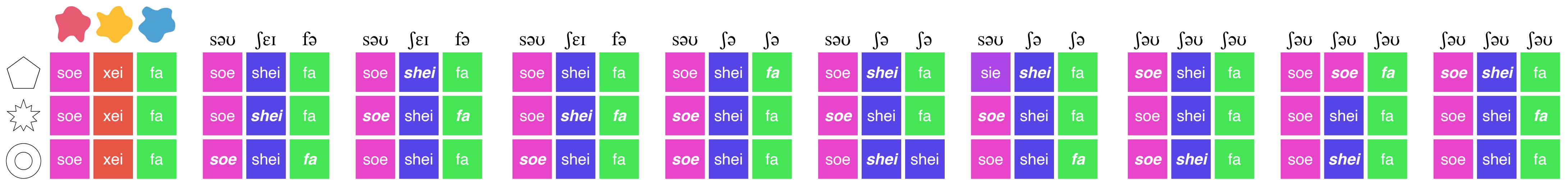
Transmission + Communication

soe	xei	fa	soe	ʃei	fe	soe	ʃei	fe	soe	ʃei	fe	soe	ʃə	ʃə	soe	ʃə	ʃə	soe	ʃə	ʃə	ʃəu	ʃəu	ʃəu	ʃəu	ʃəu	ʃəu
soe	xei	fa	soe	<i>shei</i>	fa	soe	<i>shei</i>	fa	soe	<i>shei</i>	fa	soe	<i>shei</i>	<i>fa</i>	soe	<i>shei</i>	<i>fa</i>	soe	<i>shei</i>	<i>fa</i>	soe	<i>shei</i>	<i>fa</i>	soe	<i>shei</i>	<i>fa</i>
soe	xei	fa	<i>soe</i>	<i>shei</i>	<i>fa</i>	<i>soe</i>	<i>shei</i>	<i>shei</i>	<i>soe</i>	<i>shei</i>	<i>fa</i>	<i>soe</i>	<i>shei</i>	<i>fa</i>	<i>soe</i>	<i>shei</i>	<i>fa</i>									

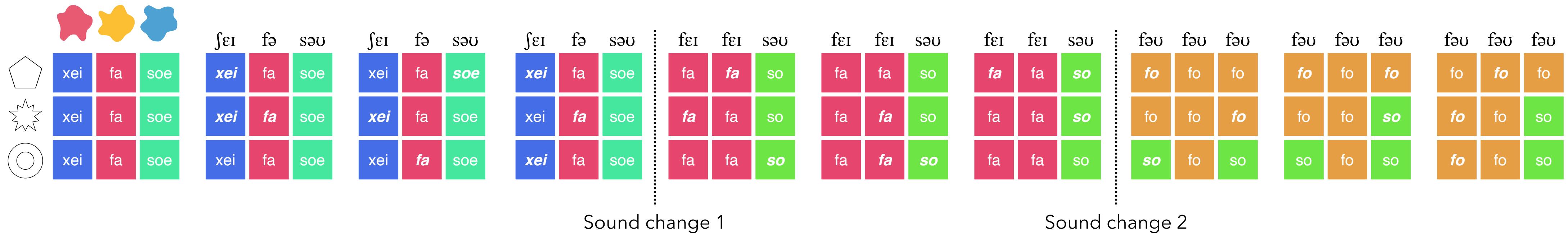
Transmission-only



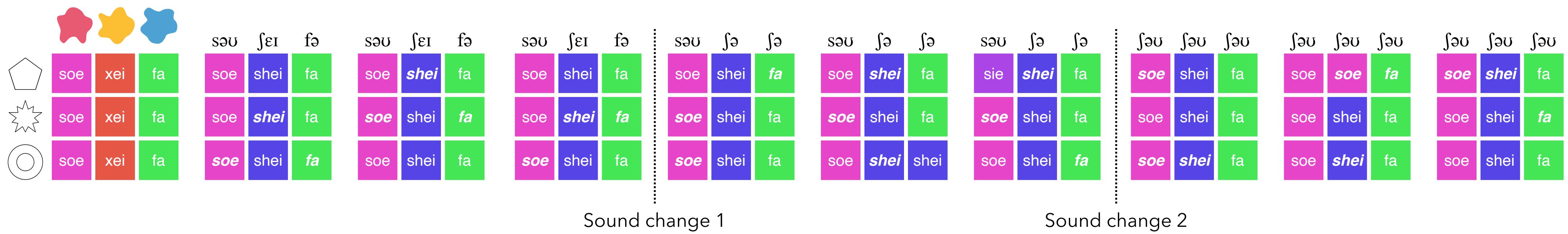
Transmission + Communication

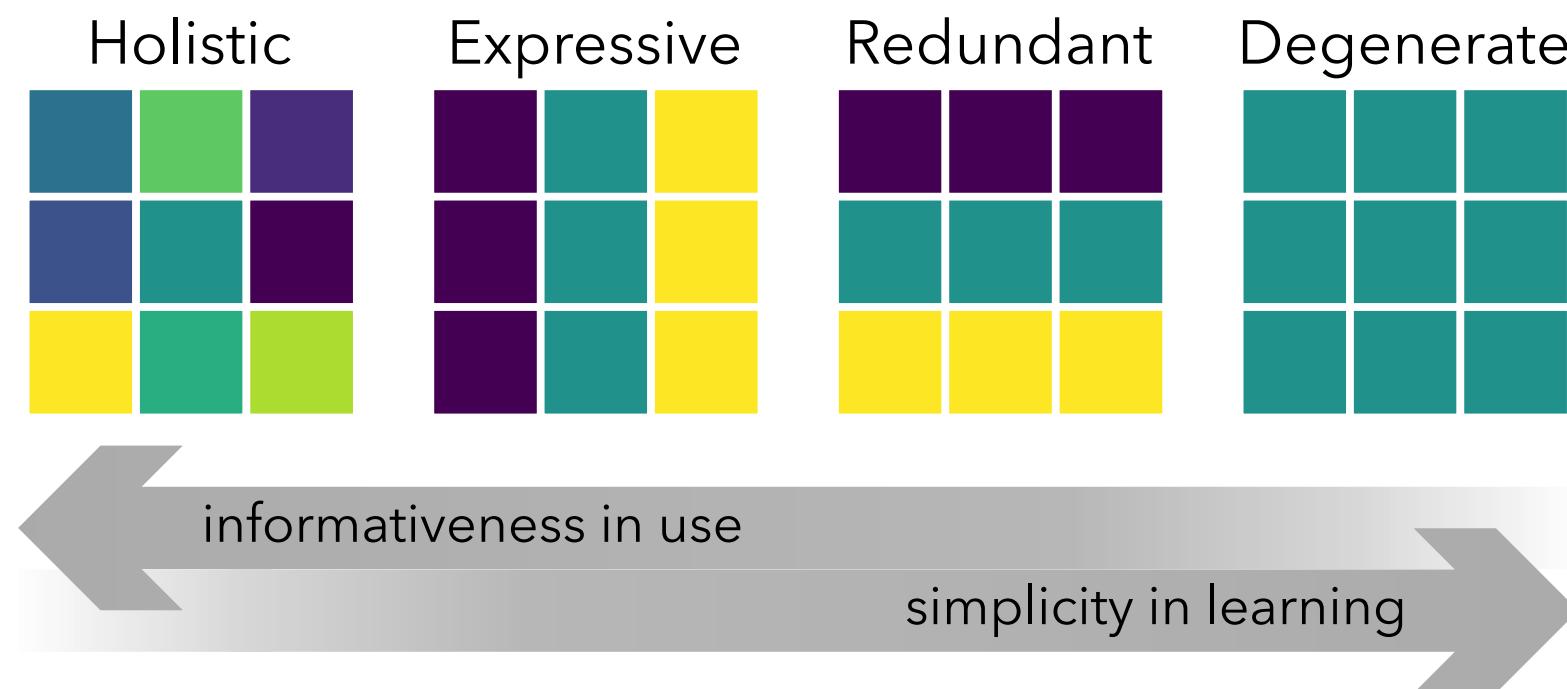
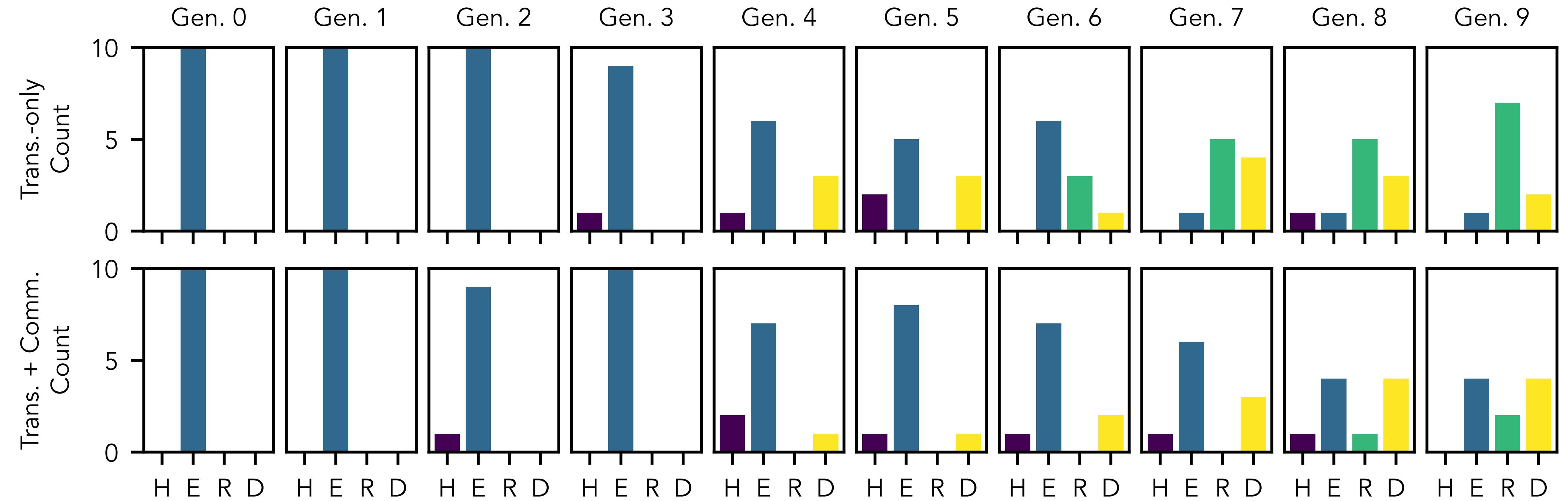


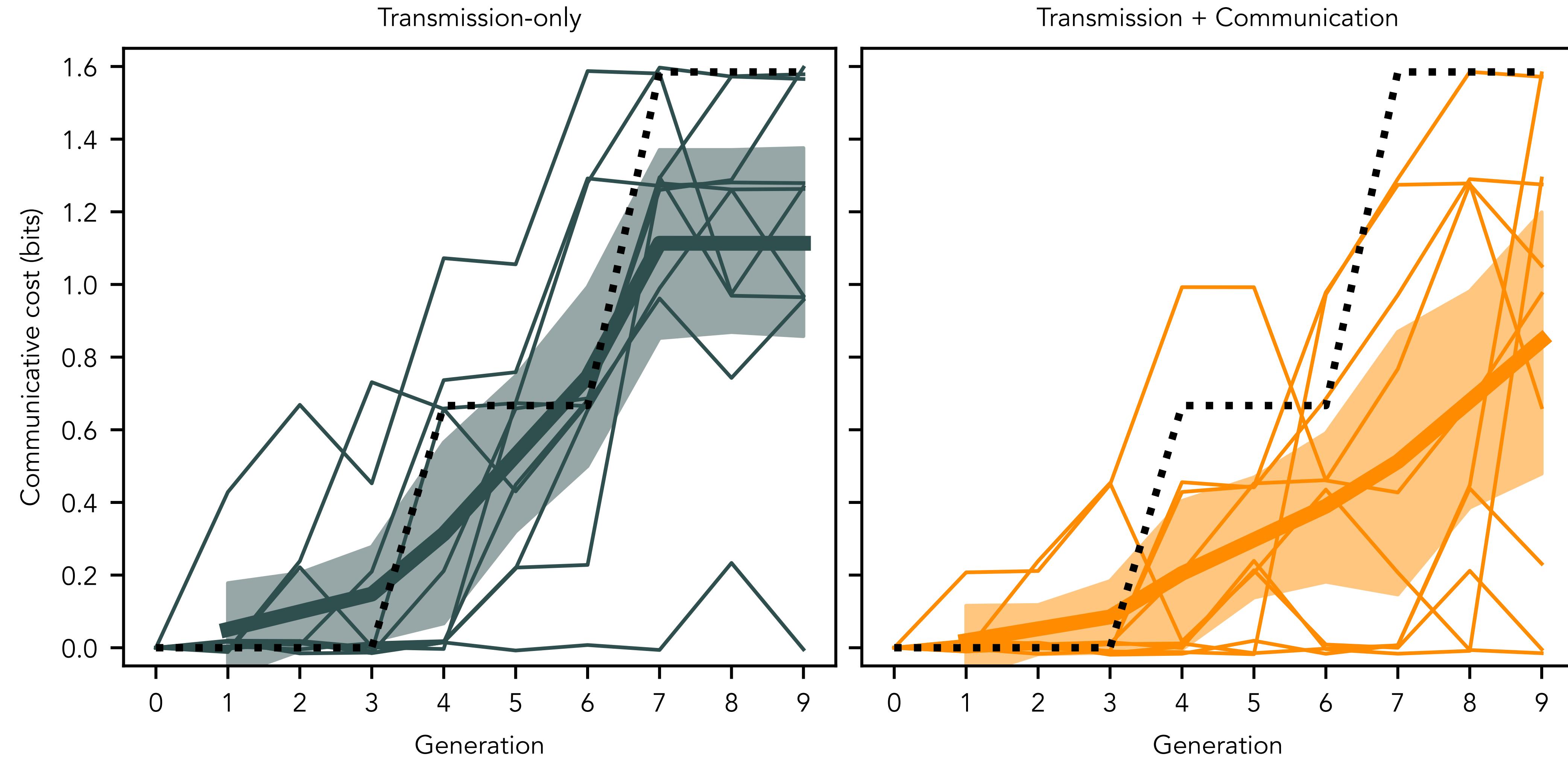
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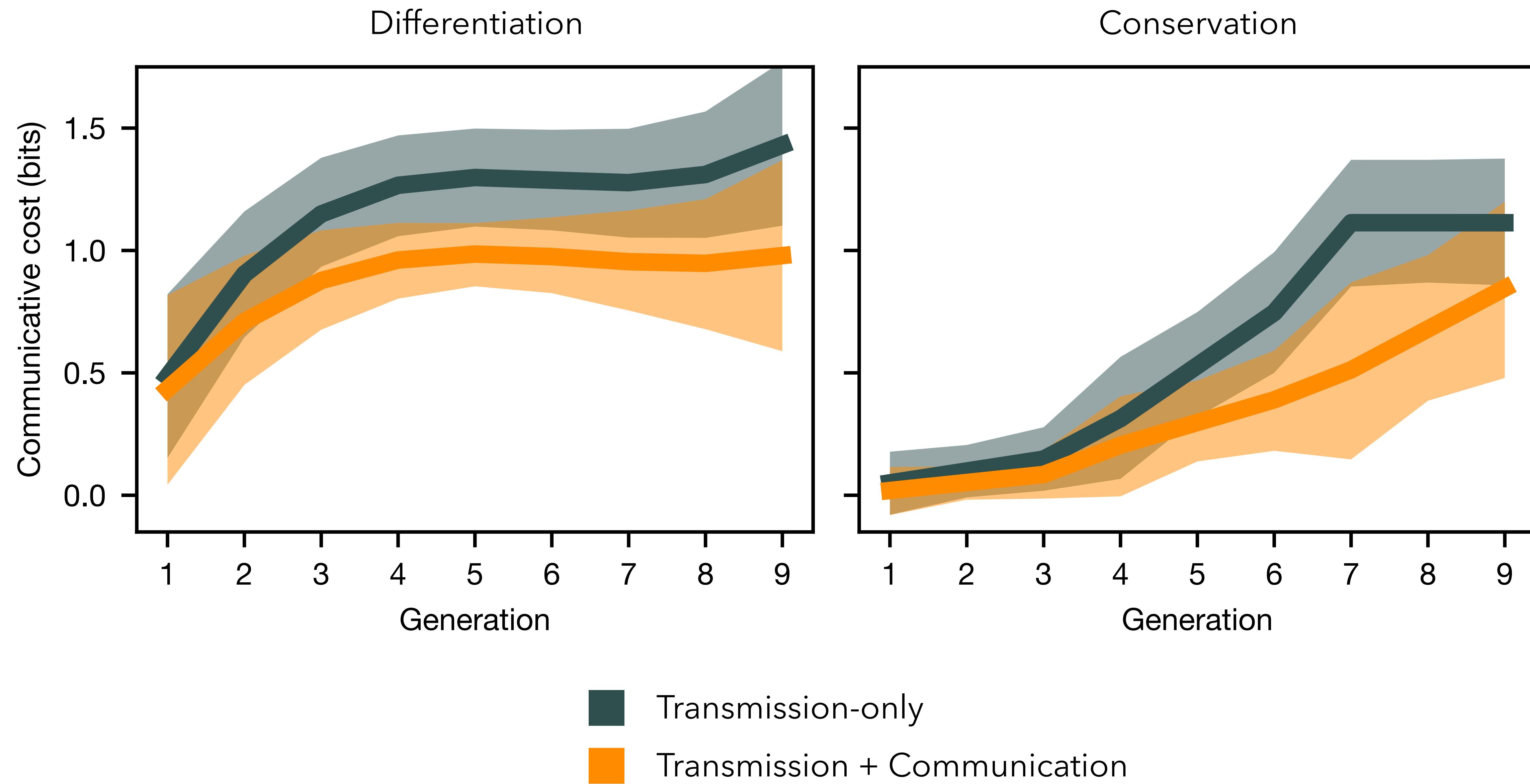
Transmission + Communication







Conclusions



Hurdles in differentiation

The apprehension problem: Participants must grasp the mechanics of the game and its incentive structure

The theory of mind problem: Participants must be able to put themselves in the shoes of their partners

The innovation problem: Participants must be capable of devising linguistic solutions

The alignment problem: Participants must be able to align with an interlocutor separated in time and space

The social problem: Participants must be prepared to rebel against their input, overcoming various social stigmas in the process

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Hurdles in conservation

The learnability problem: Participants must be able to learn the spelling system

Read more: doi.org/k3v4