

# Formal and computational models of language evolution

**Gerhard Jäger**

Gerhard.Jaeger@uni-bielefeld.de

September 21, 2006

JSSECL 2006

# Don't talk to strangers:

# Spatial EGT

# Spatial EGT

- idealized assumption of standard EGT:
  - populations are infinite
  - each pair of individuals is equally likely to interact with each other
- Stochastic EGT gives up the first assumption
- What happens if you give up second assumption as well?

# Spatial EGT

- one possible instantiation:
  - individuals are arranged in a spatial structure
  - every individual only interacts with its immediate neighbors

# Spatial EGT

Suppose we have

- set of **positions**  $pos$
- irreflexive **neighbourhood** relation  $n$  among  $pos$
- **strategy function**  $st$  maps positions and time points to random variable over strategies
- **density function**  $d$  maps positions/time points to positive real number
- **fitness function**  $f$  assigns fitness value (positive real) to positions/time points
- $Z(a, t)$ : normalization variable; accumulated weighted fitness of the neighborhood of  $a$  at time  $t$

# Spatial EGT

$$f(a, t + 1) = \sum_{b:n(a,b)} u(st(a, t), st(b, t))$$

$$d(a, t + 1) = d(a, t) \times f(a, t + 1)$$

$$P(st(a, t + 1) = i) = \frac{1}{Z(a, t + 1)} \times \sum_{(b \in \{x:n(a,x)\} \cup \{a\}) \cap \{x:st(x,t)=i\}} d(b, t + 1) \times f(b, t + 1)$$

$$Z(a, t + 1) = \sum_{b \in \{x:n(a,x)\} \cup \{a\}} d(b, t + 1) \times f(b, t + 1)$$

# Spatial structure

- two-dimensional chessboard like structure
- neighborhood: adjacent fields; each field has eight neighbors
- torus shape: upper and lower boundaries are neighbors, and likewise left and right boundaries

# Spatial Prisoner's dilemma

- one version of Prisoner's dilemma:

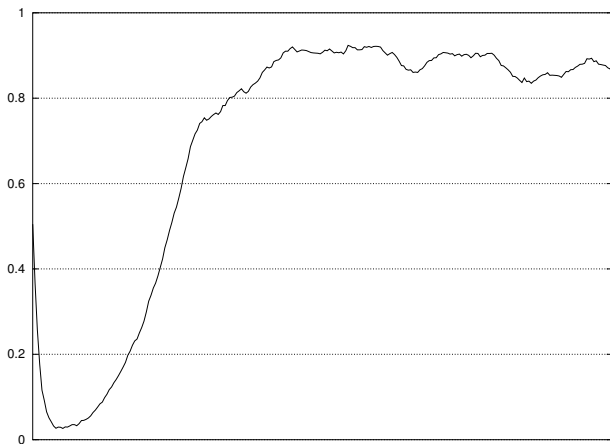
	<i>C</i>	<i>D</i>
<i>C</i>	5,5	1,6
<i>D</i>	6,1	2,2

- standard EGT: one ESS: (*D*, *D*)
- spatial EGT:
  - only interaction with neighbors
  - neighbors are likely to be “related” to each other
  - increased likelihood of interactions between individuals with identical strategies
  - favors strategies with high utility against itself, even if not NE



# Spatial Prisoner's dilemma

- proportion of C-players in a spatial Prisoner's dilemma:



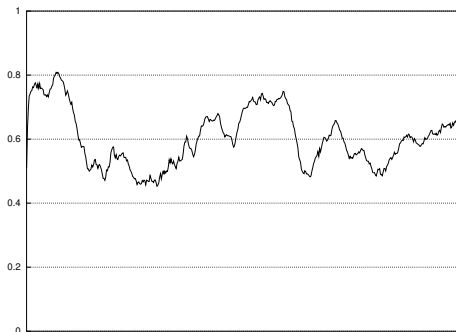
# Spatial Hawks and Doves

- spatial evolution generally favors intra-strategy altruism
- should favor Doves over Hawks

	H	D
H	1	7
D	2	3

# Spatial Hawks and Doves

- development of the proportion of hawks in spatial HaD
- proportion of doves is most of the time higher than in the ESS (20%)



# Game of communication

- row strategies:
  - $T$ : talk
  - $S$ : remain silent
- column strategies
  - $A$ : pay attention
  - $I$ : ignore
- only one ESS:  $(S, I)$

	A	I
T	1,2	0,1
S	1,0	1,1

# Spatial game of communication

- symmetrized game of communication:

	$(T, A)$	$(T, I)$	$(S, A)$	$(S, I)$
$(T, A)$	3	2	1	0
$(T, I)$	2	1	2	1
$(S, A)$	3	3	1	1
$(S, I)$	2	2	2	2

- “cooperative” strategy pair  $(T, A)$  forms stable clusters