# Supplement — model description

This description follows the standardized ODD protocol for agent-based models (ABMs; Grimm et al. 2006).

*Purpose*

We developed an ABM to simulate the interaction described in the Biblical story of Shibboleth. The aim of the model is to determine whether cost or risk of detection is a better prediction of outcome in an intergroup competition.

*Parameters and schedule*

|  |  |  |
| --- | --- | --- |
| Variable | Type | Description |
| N | Global | Number of individuals in blue and green groups; total population = 2 \* N; default = 50 |
| generations | Global | Number of generations per model run; default = 200 |
| cost | Global | Cost individual pays on detection; range 0-100; default = 10 |
| B | Global | Variable indicating the global boundaries of mimicry and sensitivity; where 0 is lowest and 1 is highest; range 0-1; default = 0.2 |
| Traits | Global | Number of signals on blue-green spectrum that individuals may possess; each individual initiates with only 1 trait; default = 10 |
| Mimicry boundaries | Global | Boundaries of possible agent-level mimicry score, determined initially by (traits-1) \* B. |
| Tolerance boundaries | Global | Boundaries of possible agent-level sensitivity score, determined initially by (traits-1) \* B. |
| Adjustment | Global | Determines tolerance boundary adjustment at end of each generation. Globally defined as round((traits-1)\*B). Adjustment is negative if mimics make up at least 50% of population; adjustment is negative if mimics make up less than 50% population. |
| Potential to reproduce (PTR) | Agent | Probability that a given individual will reproduce; individuals initiate with random normal PTR around 50; range 0-100 |
| Mimicry | Agent | An individual’s ability to mimic signals, where 0 is lowest and mimicry boundaries is highest. Individuals initiate with random mimicry sampling from mimicry boundaries. |
| Sensitivity | Agent | An individual’s ability to detect mimicry, where 0 is lowest and tolerance boundaries is highest. Individuals initiate with random sampling from tolerance boundaries. |

**Table S1: Overview of agent- and global-level variables in model**

We represent time discreetly over generations; we do not consider space. At each generation, agents follow the commands described in the schedule (**Figure S1**).

![Diagram

Description automatically generated]()

**Figure S1: Schedule overview**

*Schedule overview*

1. Random dyads form (agent from blue group approaches agent from green group)
2. Agent from blue group requests to enter group and to receive help
3. Agent from green group initiates detection test
   1. If agent from blue group passes test, green agent pays cost and all green agents lose cost/10 plus individual sensitivity score
   2. If agent from blue group fails test, blue agent pays cost and all blue agents lose cost/10 plus individual mimicry score
4. Tolerance boundaries adjusted by adjustment (see **Table S1**)
   1. If mimics make up at least 50% of total population, tolerance boundaries are lowered by adjustment
   2. If mimics make up less than 25% of total population, tolerance boundaries are raised by adjustment.
5. Entire population reproduces with probability PTR

*Design concepts*

*Emergence —* the relationship between cost and risk of detection emerges from interactions between agents.

*Prediction* — agents have no memories and the interactions are considered as standalone events in a given cultural or genetic generation.

*Sensing* *vs signalling* — green agents have sensory apparatuses; blue agents can only signal

*Interaction* — dyadic interactions are formed randomly; blue agents attempt to trick green agents into providing aid

*Stochasticity* — dyadic interactions are random; PTR is probabilistic

*Observation* — we report data per model over 10,500 runs exploring variations in the cost and B variables; we compare results with a stochastic drift model without selection that we ran 5,000 times

*Input* — we assumed a scenario where blue agents asked green individuals for aid, and green individuals attempted to determine whether the signal indicating need came from a true group member. We also assumed that tolerance boundaries would be frequency-dependent, and where mimics made up less than half the total population, tolerance would become more relaxed; we assumed the opposite scenario where mimics made up at least 50% of the population.