

Model analysis of replication of Nowak, M.A. and K. Sigmund (1998) Evolution of indirect reciprocity by image scoring, *Nature* 393: 573 – 577

When we include h , the threshold of the donor agent, and imperfect information. We can replicate Figure 4 of Nowak and Sigmund (1998). Nowak and Sigmund are not clear on the level of information incompleteness in their simulation results. We use a 50% probability that an agent sees the interaction of two other agents. We ran the model for 500,000 ticks and present the results in the figures below

In Figure 1 show the results of one typical run with no mutation, $n=100$, $m=125$. The figures show the distribution of the k values, strategies in the population. They converge to one value.

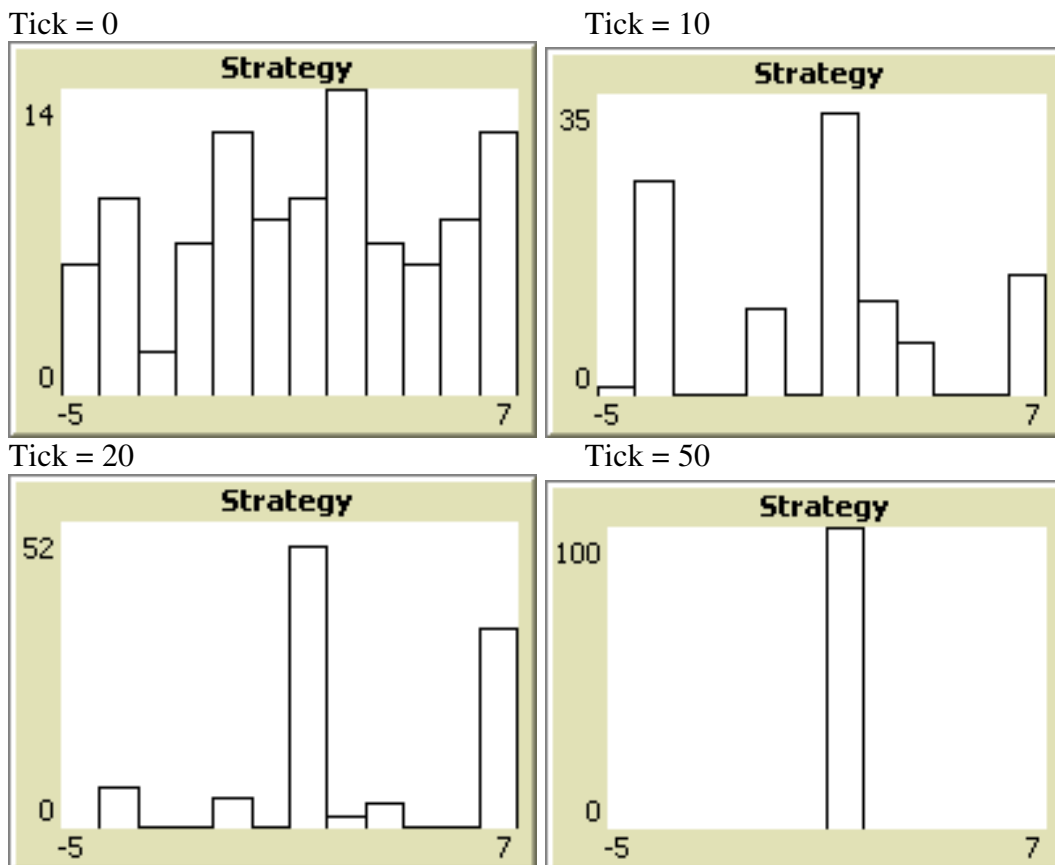


Figure 1. Distribution of strategies, k , for a typical run.

Figure 2 shows the long term dynamics of one simulation with $n=100$ and $m=300$. We included a mutation of 0.001. Figure 2a shows that there are periods of cooperation with periods of defection in between. Figure 2b show the evolution of the average value of k , and Figure 2c shows the distribution of k values for 500,000 timesteps.

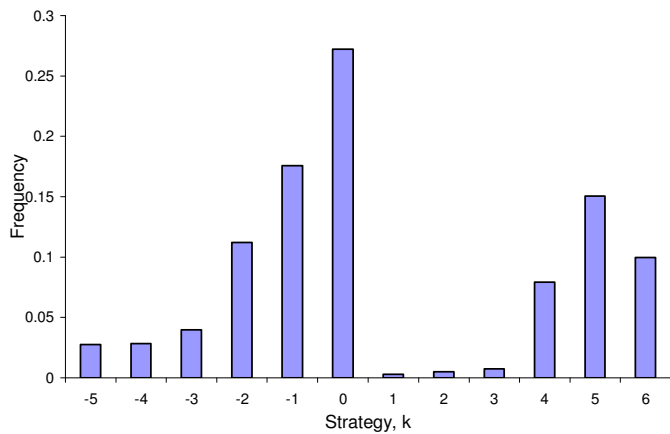
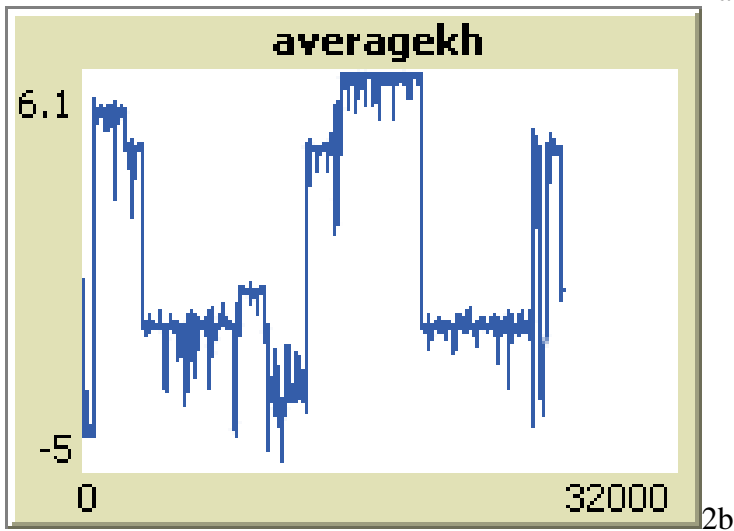
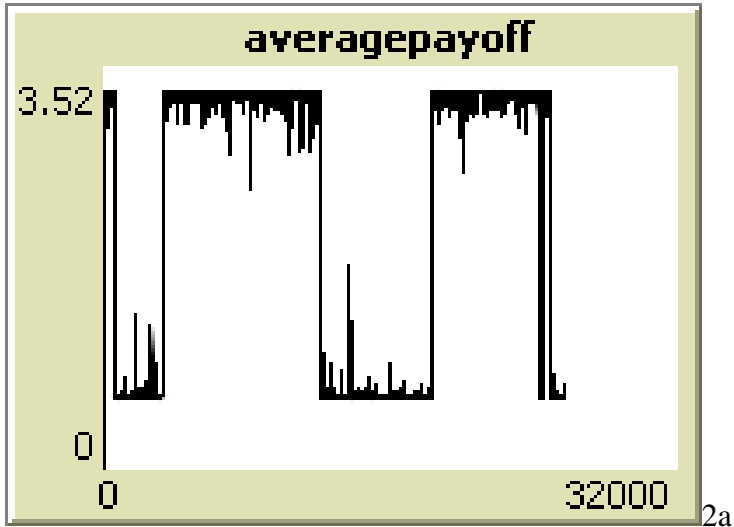
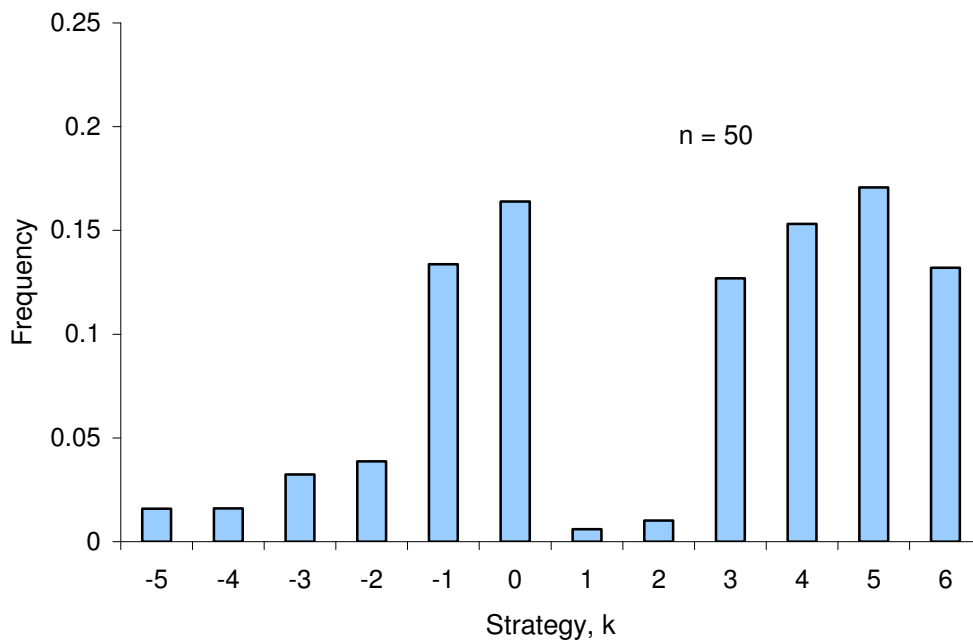
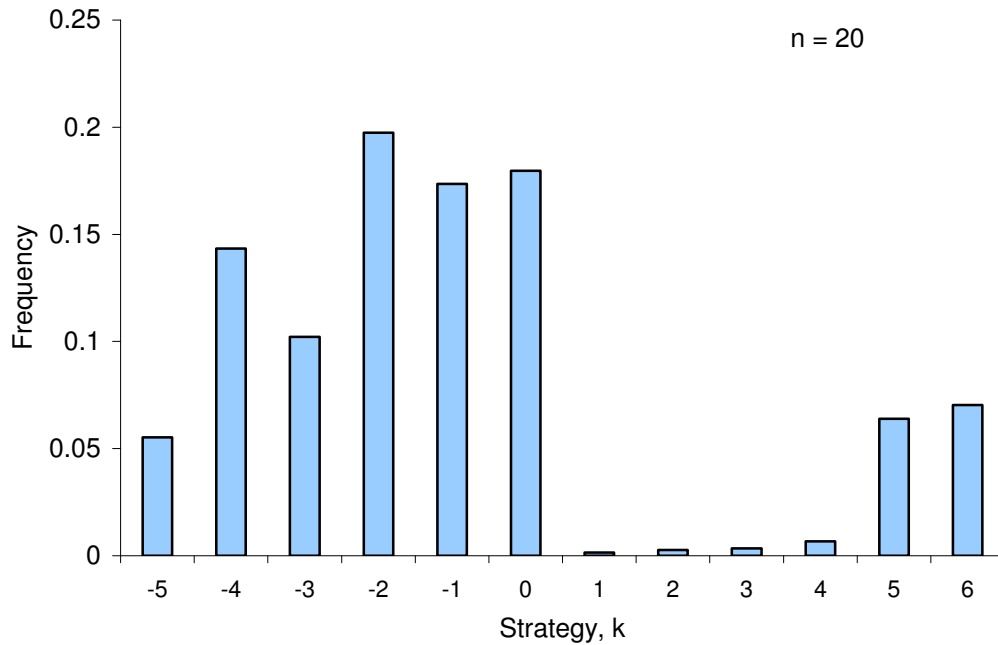


Figure 3 shows the consequences of incomplete information. In each simulation of 500,000 ticks the average number of agents that observed the interaction is 10. But Figure 3a has $n=20$ and $m=200$, Figure 3b has $n=50$ and $m=500$, and Figure 3c has $n=100$ and $m=1000$. We see that with larger numbers the values of k are larger and as a consequence there is less cooperation.



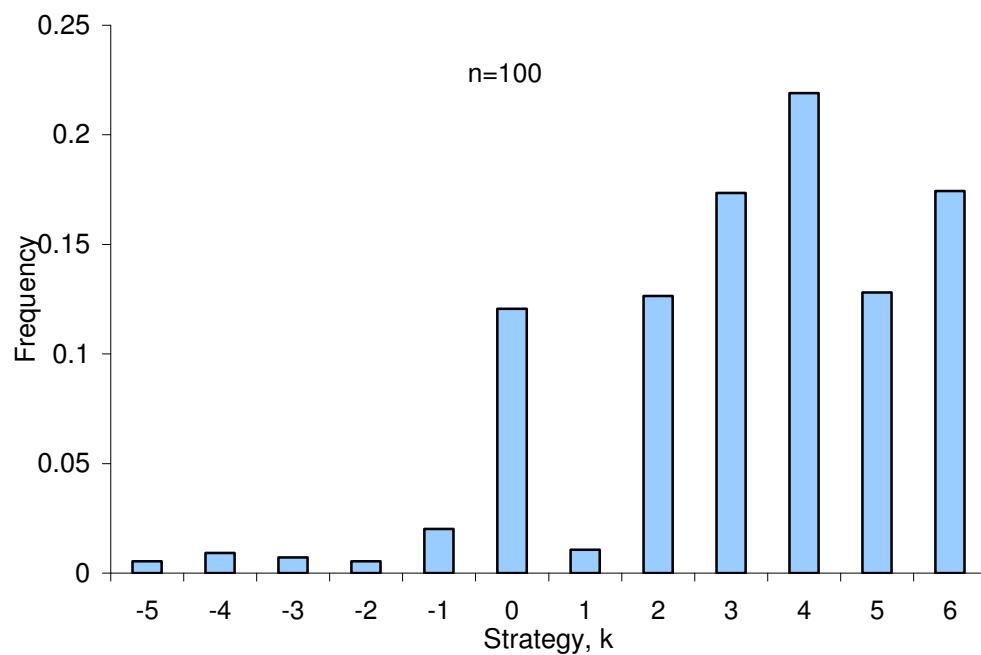


Figure 3: Distribution of k strategy based on simulation of 500,000 ticks.

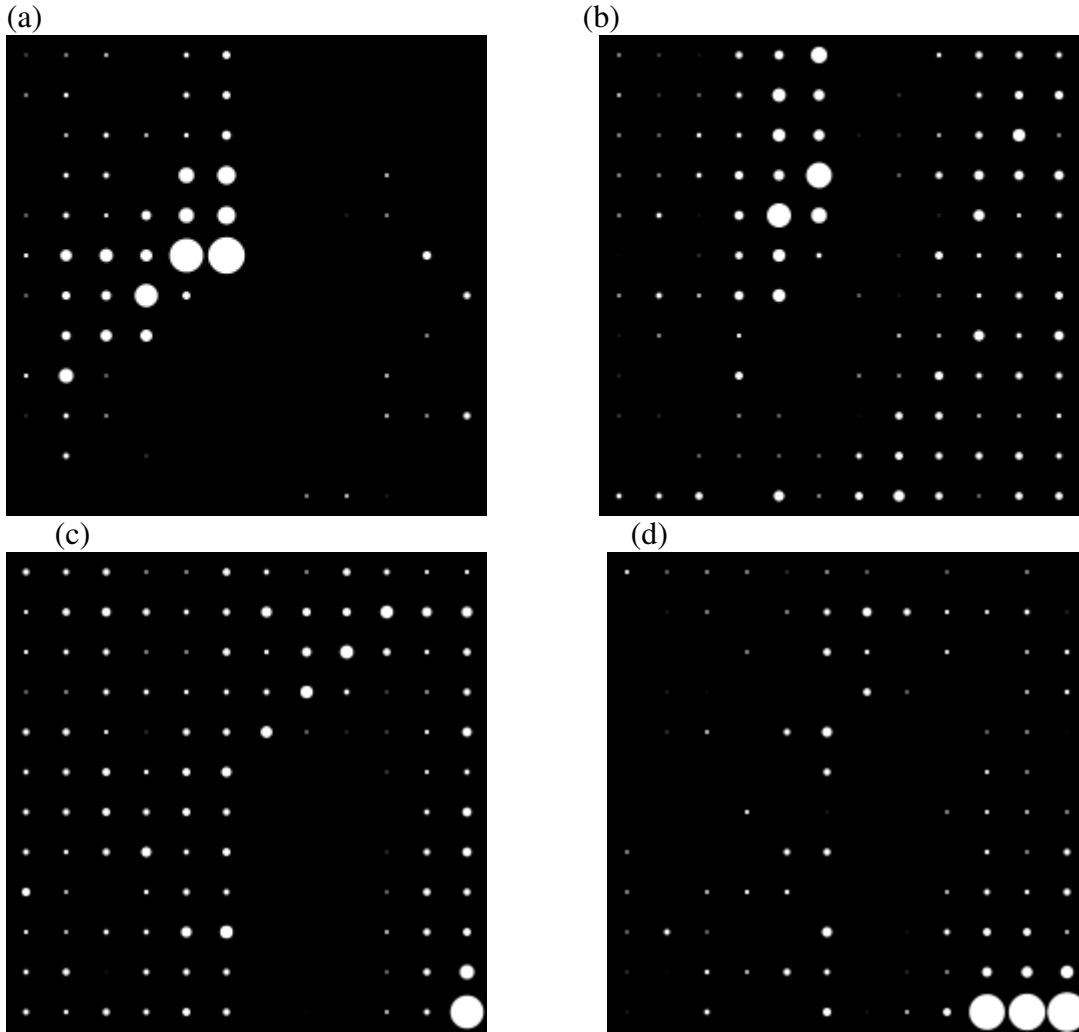


Figure 4. The figures show the frequency distribution of strategies that are defined by their k and h values sampled over 500,000 generations. The vertical axis is the h -value between -5 and 6, and the horizontal axis is the k -value between -5 and 6. For figures 4a and 4b. Agents cooperate if the image score of the recipient is at least k AND if their own image score is less than h . For figures 4c and 4d. Agents cooperate if the image score of the recipient is at least k OR if their own image score is less than h . $m = 500$ rounds per generation and $n = 100$ agents. There is a mutation rate of 0.1 percent. Figures 4a and 4c assume full information, while figures 4b and 4d assume 50% visibility of the actions of the players.