Impact of historical information in human coordination

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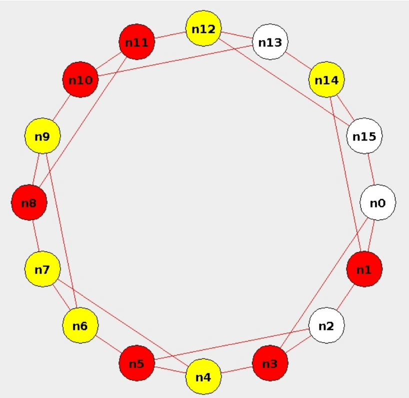
Introduction

- We are interested in how people solve combinatorial problems in a distributed fashion, a simple example of human coordination.
- Everyone cannot always communicate with everyone else, i.e. **network** coordination.
- We follow work by Kearns *et al.* in studying human coordination in a laboratory setting.
- Kearns *et al.* had subjects solve the network coloring game for financial incentives.
- Network coloring is a well studied combinatorial problem that is simple to explain.

The Network Coloring Game



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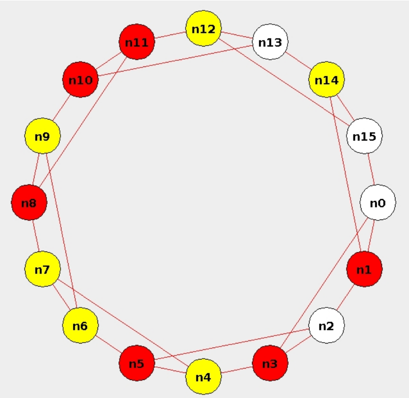

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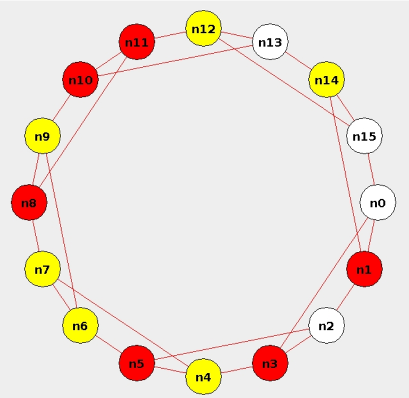

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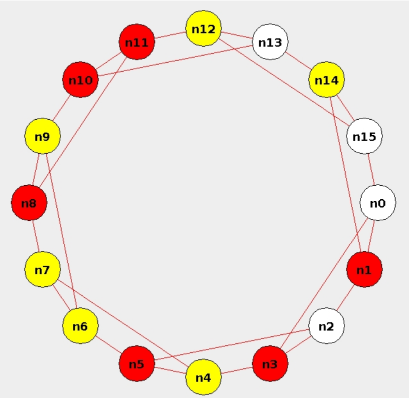

1. Each subject controls the color of one node.
2. Subjects can only see colors of neighboring nodes.
3. Subjects are not given the structure of the network.
4. A network is 2-colored if all nodes are a different color than their neighbors.

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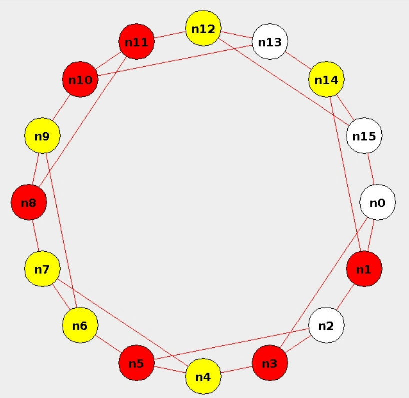

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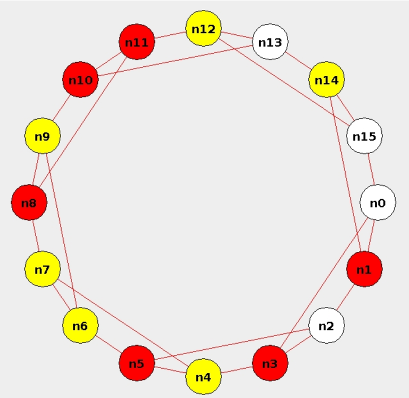

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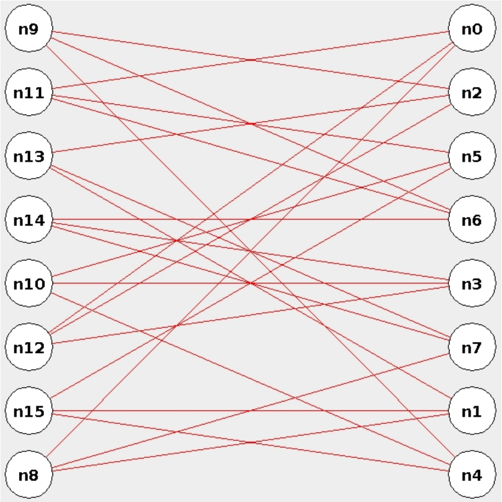
2. Subjects can only see colors of neighboring nodes.
3. Subjects are not given the structure of the network.
4. A network is 2-colored if all nodes are a different color than their neighbors.
5. Subjects receive 1 for 2-coloring the network in under 3 minutes, 0 otherwise.
6. Subjects repeatedly play the 2-coloring game for 90 minutes.

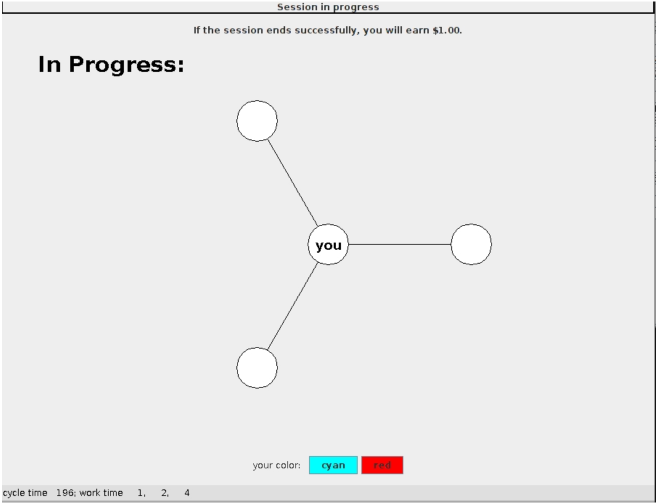
The Network Coloring Game

A full network (subjects cannot see this):



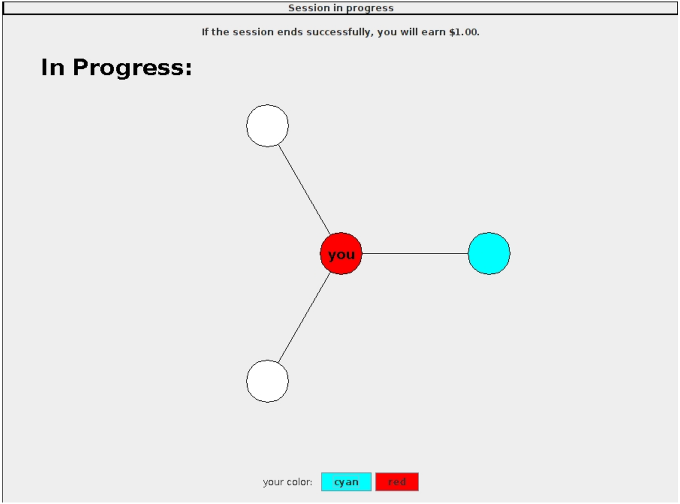
The Network Coloring Game

A subject's view before selecting a color:



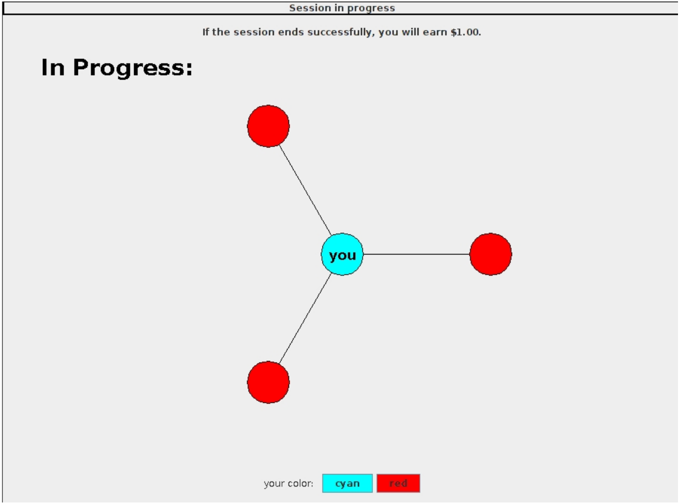
The Network Coloring Game

A subject's view during the game:



The Network Coloring Game

A 2-colored neighborhood:



Player Strategies

What strategies do humans use to coordinate?

Player Strategies

What strategies do humans use to coordinate?

- Humans have bounded memory and limited computation power.
- Psychologists tell us that humans use “fast and frugal” heuristics to make decisions [Gigerenzer and Goldstein in Psych. Review ’96]
- Fast and frugal heuristics use limited knowledge and biases to quickly make decisions.

Player Strategies

What strategies do humans use to coordinate?

Kearns et al.:

1. Minimize number of current local conflicts, breaking ties randomly.
2. Qualitatively seems to agree with some of their experiments.

Player Strategies

What strategies do humans use to coordinate?

Israeli et al.:

1. Pick a color with probability inversely proportional to number of neighbors with that color.
2. If all nodes follow this strategy, converges to a 2-coloring in expected $O(m^2 n \log n)$ time.

Player Strategies

What strategies do humans use to coordinate?

Israeli et al. - strategy on a ring for nodes with a conflict:

1. Change color with probability $p = 1/2$, while memorizing old color and the colors of two neighbors.
2. If any neighbor changes its color during the first round, restore the previous color.
3. Converges to a 2-coloring in expected $O(n^2)$ time.

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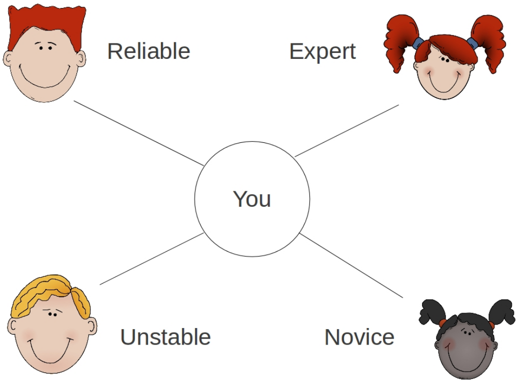
This is a simple strategy that uses the **history** of local interactions.

Motivation

It seems plausible that humans use history in their decision making, possibly to form models of network neighbors.

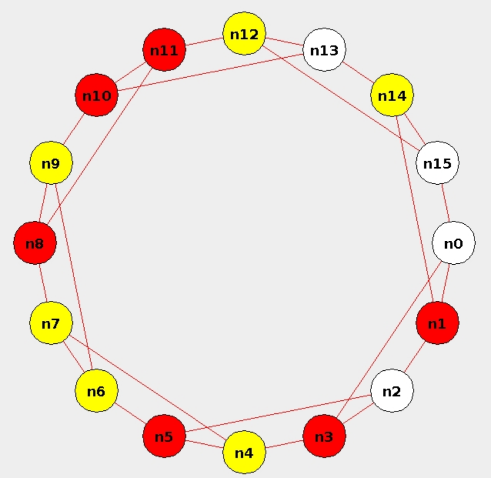


Research Questions

1. Do humans use the history of local interactions in their strategies in coordination?
2. Do they use history to their advantage?

Experiments

We follow work by Kearns et al. in modeling human coordination as graph coloring.



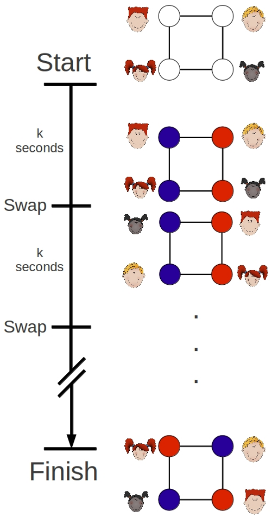
Experiments

We conducted two experiments tailored to control subjects' use of history.

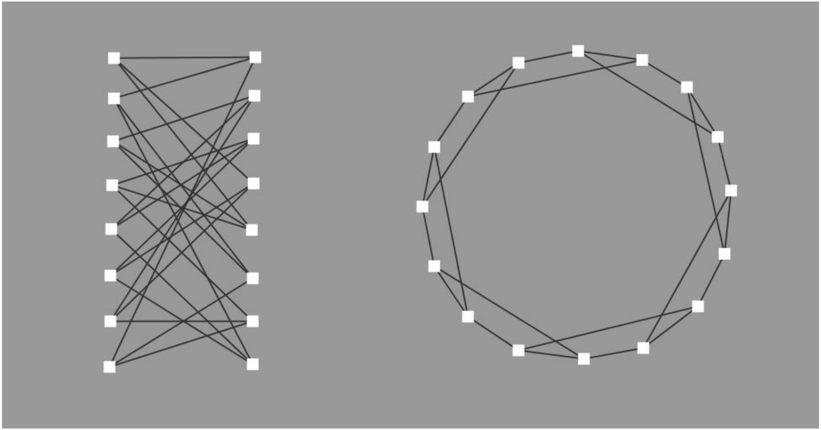
1. Swap
2. Restart

Swap Experiment

Periodically swap subjects while maintaining the global coloring state of the network.



Swap Experiment Topologies



- Random 3-Regular (left) and Degree 3-cycle (right)
- Keep degree constant while varying diameter.

Swap Experiments

Topology	**Swap Time**	**Number of Games**
Random 3-Regular	Never swap	5
Random 3-Regular	10 seconds	9
Random 3-Regular	5 seconds	6
Degree-3 Cycle	Never swap	5
Degree-3 Cycle	10 seconds	7
Degree-3 Cycle	5 seconds	8

Games presented in random order.

Swap Experiment Dynamics

How can we visualize the dynamics of the games?

Swap Experiment Dynamics

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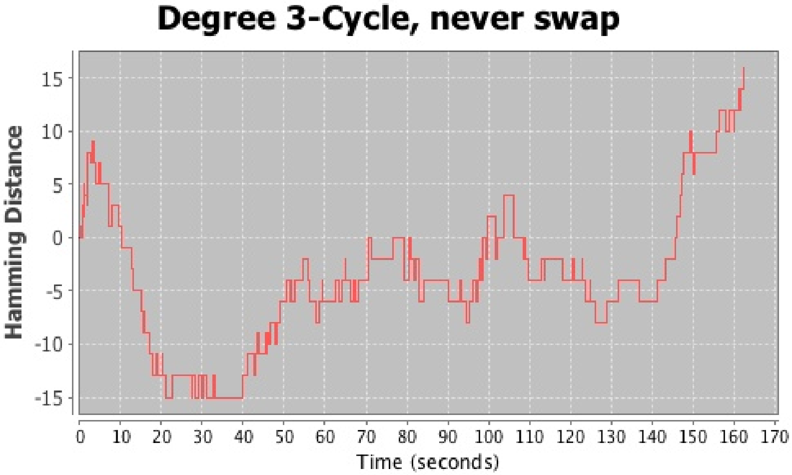
Hamming Distance:

1. There are two possible 2-coloring solutions.
2. If a node's color agrees with solution 1, assign it +1.
3. If a node's color agrees with solution 2, assign it -1.
4. If a node is uncolored, assign it 0.
5. Sum of all nodes' values is the Hamming distance.
6. +16 and -16 are solutions.

Swap Experiment Dynamics



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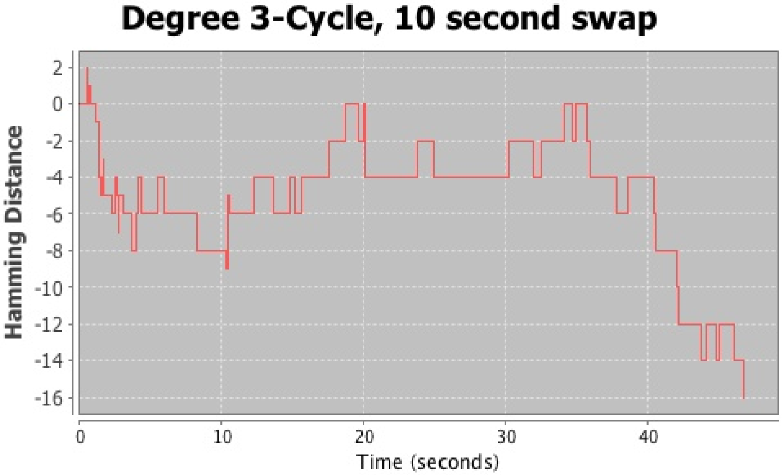

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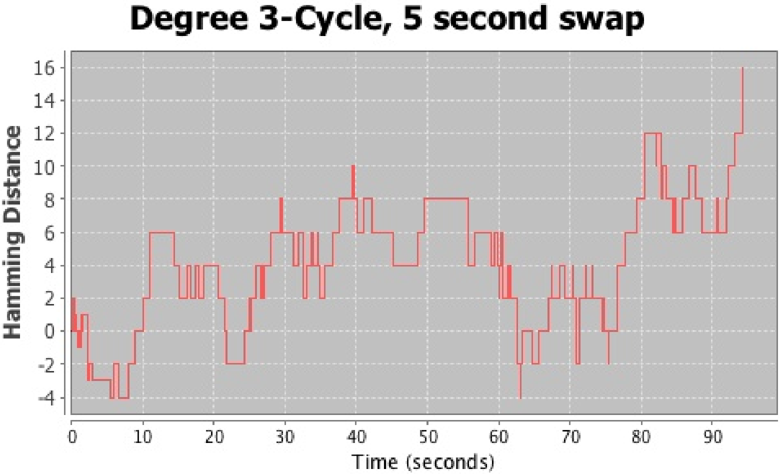
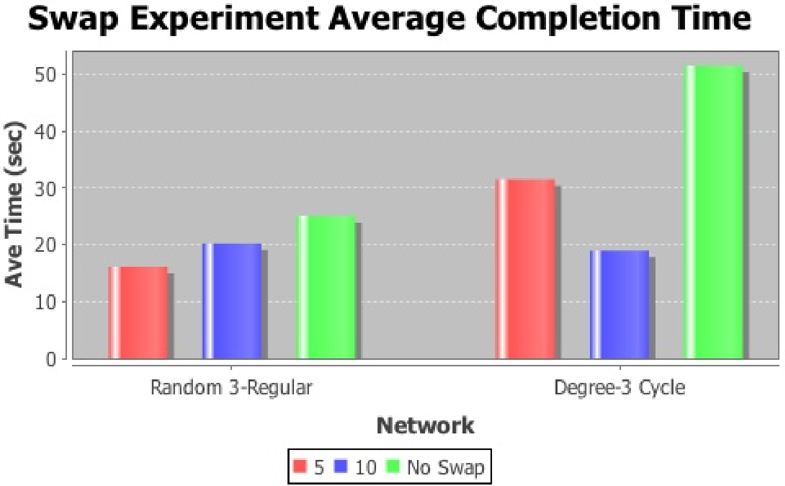


Swap Experiment Results



Swap Experiment Results

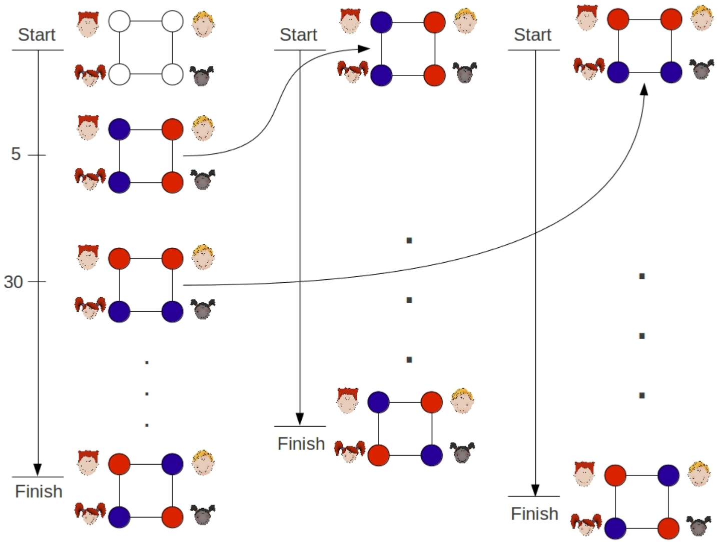
- We don't learn anything from average completion time.
- Many games did not last long enough to receive the swap treatment.
- Swapping has multiple unintended treatments.
  1. Distributes strategies (distributes incompetence)
  2. Swapping seems to induce players to make a change.

Restart Experiment

Two phase experiment:

1. Subjects performed a series of two coloring tasks in which all network nodes began with no color.
2. Subjects performed another series of two coloring tasks in which the initial color of each node was taken from a 30 second or 5 second checkpoint of a game from the first phase.

Restart Experiment



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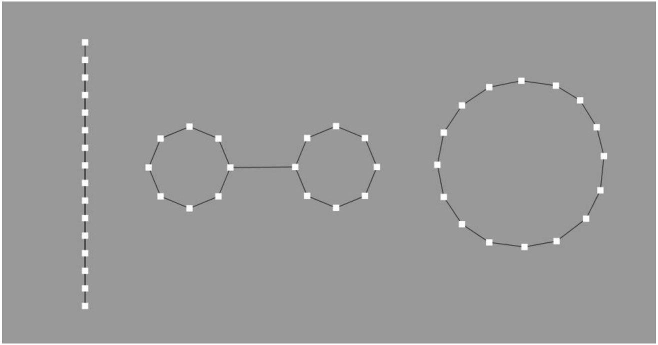

- Line (left), Barbell (center), and Cycle (right)
- Small degree networks
- Protocol requires parent games to last over 35 seconds, and these networks are the most difficult to 2-color.

Restart Experiment

Topology	**Number of Games**
Line	3
Barbell	4
Cycle	4

- Each experiment consists of one parent game, one 5-second restart game, and one 30-second restart game.
- All parent games run in a random order in phase 1.
- All restart games run in a random order in phase 2.

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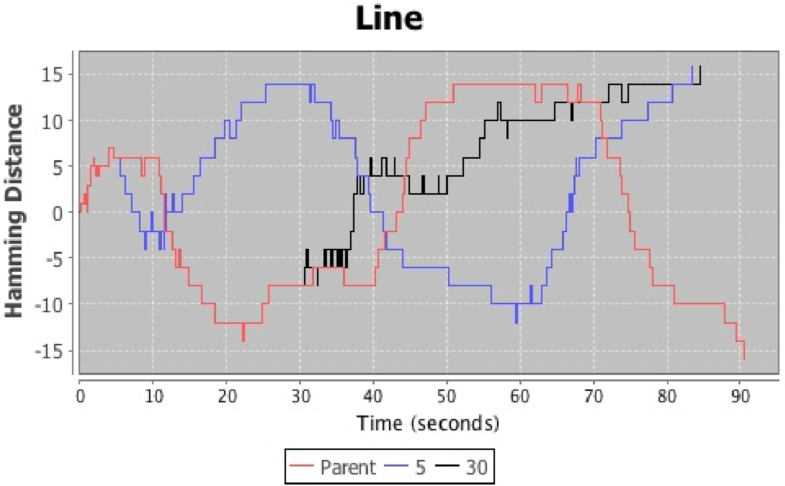

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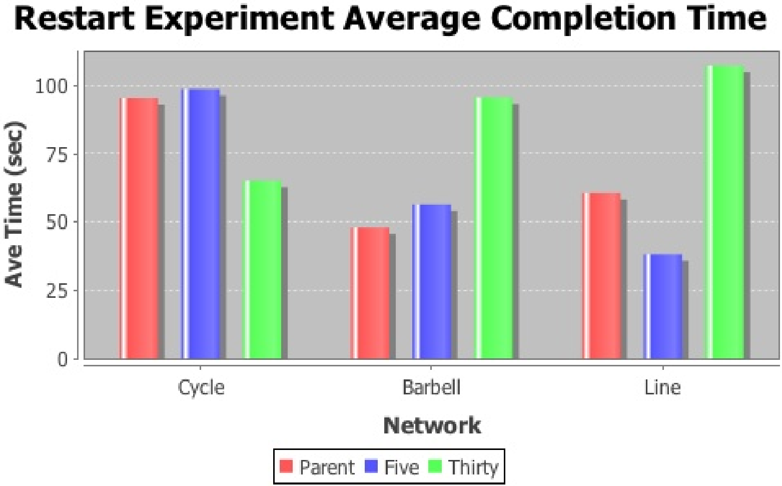


Restart Experiment Results

- We don't learn much from average completion time.
- Variance in completion time is high.
- History usage might be too short-term to be captured with this protocol.
- We need more data to draw conclusions from average completion time.

Simulations

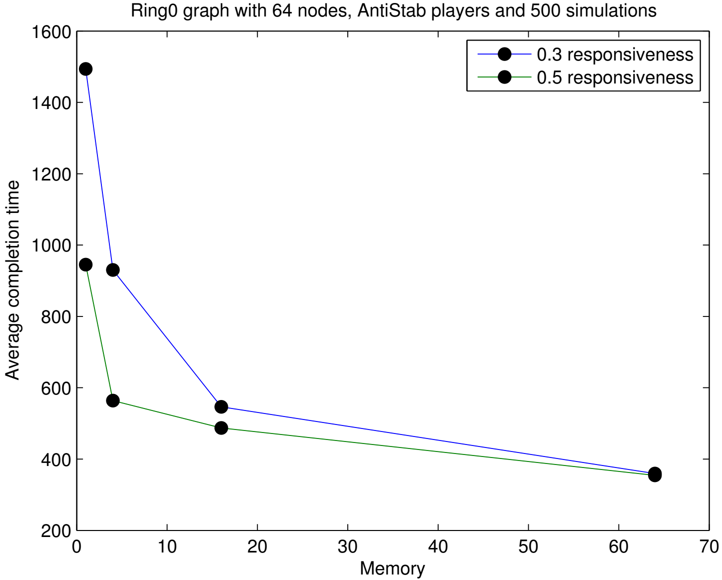
Can we design ”natural” human strategies that use history?

- We have developed a framework for designing natural human uses of history.
- Players non-deterministically minimize local conflicts.
- Each neighbor is assigned a weight.
- Weight is based on a neighbor’s history.
- Minimize weighted local conflicts.
- Conflicts with low weight neighbors are ignored.
- Amount of history used is a parameter.

Simulations

- We have simulated three ”natural” weighting schemes.
- We varied several parameters:
  1. Topology
  2. Reactivity
  3. History
  4. Weighting scheme
- Result: history has a significant effect, but its precise effect is highly dependent on all parameters.

Simulations



Discussion

- Preliminary analysis indicates that recent history seems to matter when resolving conflicts.
- We haven't learned much about its effect on performance!
- Simulations demonstrate that simple uses of history do have an effect on performance.
- Restart experiment protocol is a general technique for controlling history in a wide class of games.
- Swap experiment protocol has too many unintended treatments.
- We don't learn anything from average completion time on swap and restart experiments.
- Unclear whether graph coloring is conducive to a rich use of local history.
- Restart protocol could be more revealing in a richer game.