

Center for Game Science



- Over 35 PhD, ugrads, SDEs, designers, artists
- 6 games currently in development



Symbiotic Human-Computer Computing architecture



Solving Hard Problems with Human-Computer Symbiosis

Coadaptation:

1. People → Experts
2. Programs/Games → Optimal problem tools

Games are an ideal vehicle of coadaptation



Center for Game Science



- Over 35 PhD, ugrads, SDEs, designers, artists
- 6 games currently in development



The Challenge:

1. hard to make an entertaining game
 2. even harder do it and solve a hard problem
 - constraints on game design
 - make real discovery, really learn something
 - Long term involvement
- cannot separate the two objectives
 - Very different than standard game design

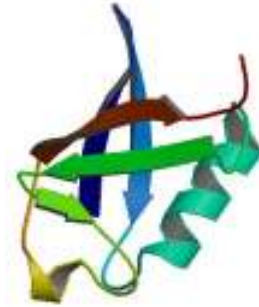


Evidence?

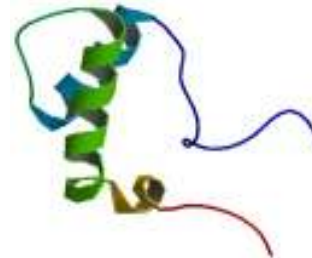


Proteins

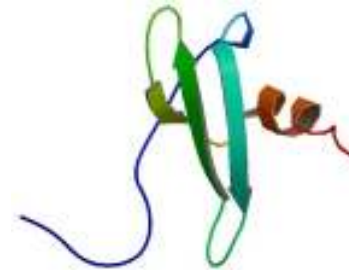
MQIFVKTLTGKTILEVEPSDTIE...



MGKYDKQIDLSTVDLKKLRVKEL...



KPVSLSYRCPCRFFESHVARANV...



⋮
Sequence

⋮
3D Structure



Foldit

Full Mode

Rank: 317 Score: 2534 Beginner Puzzle 8 (c150): Fruit Fly
Soloist No conditions

Group Competitions

Group Name	Score
1 Rice Biochemistry	9174
2 Texas Commonwealth	9168
3 Ukraine	9088
4 Texas Canada	9085
5 FlexibleBioChem	9073
6 SETI Germany	9070
7 Biochem	9001

Soloist Competitions

Player Name	Current	Best
1 Mike Crandall for Physics	9242	9242
2 wallace	9235	9235
3 vs719	9222	9222
4 chadko	9211	9211
5 kate_karjan	9196	9196
6 JIM02ee	9185	9185
7 gharic	9183	9183

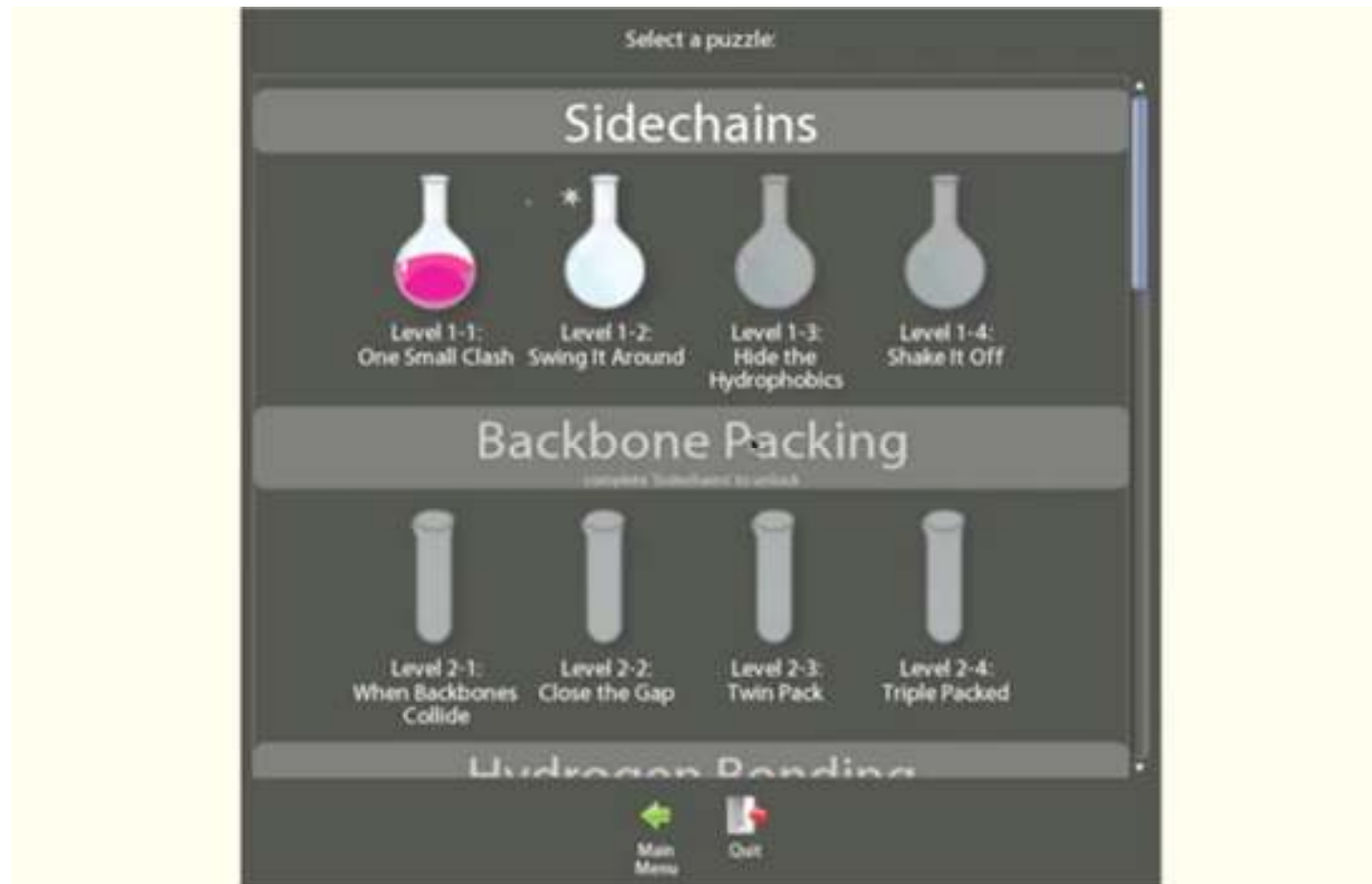
Shake Sidechains Wiggle All Wiggle Backbone Wiggle Sidechains Freeze Protein Remove Bands Disable Bands Align Guide Reset Structures Reset Puzzle Help Glossary

Chat - Group Chat - Puzzle Chat - Global Notification

auto show auto show auto show auto show

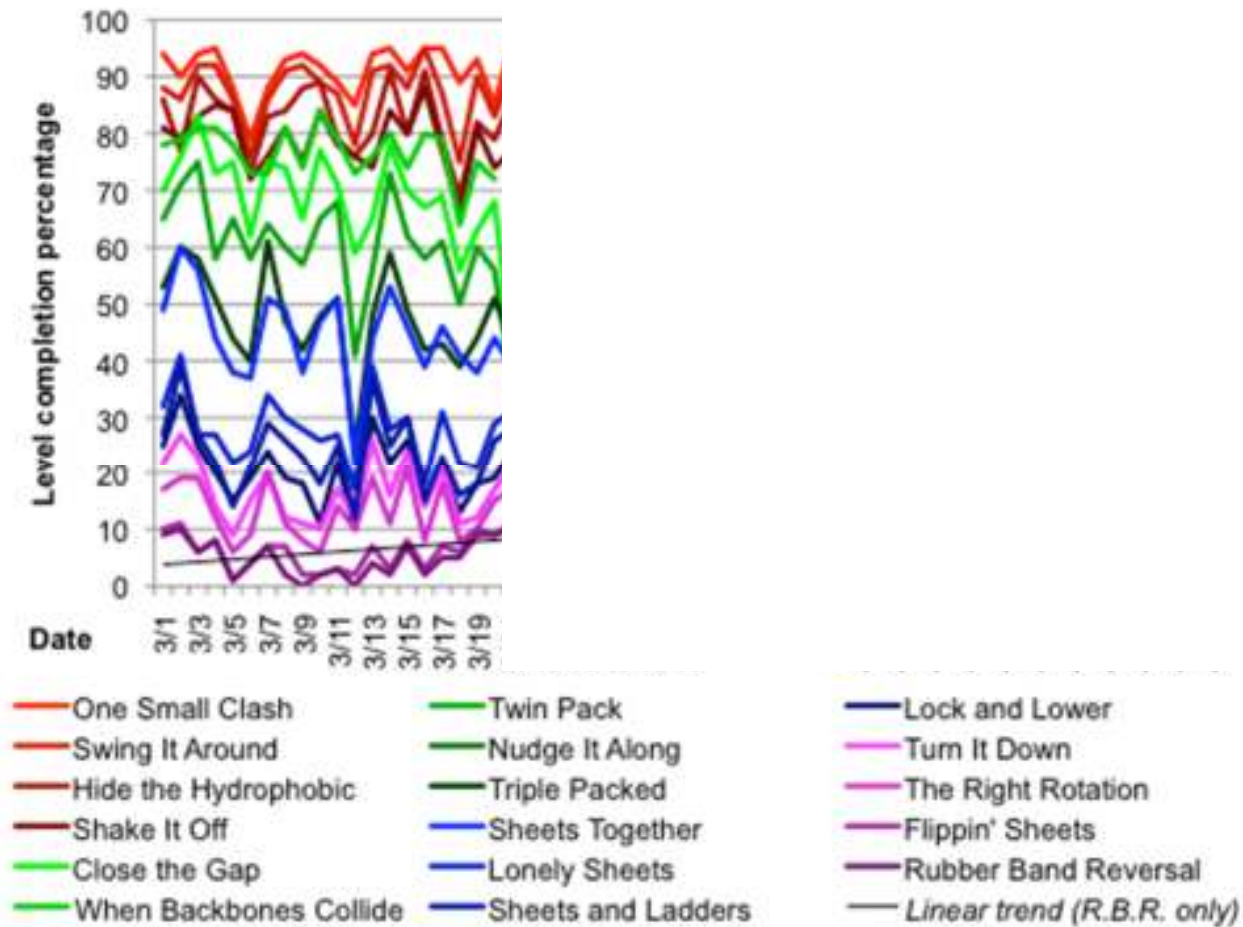


Training



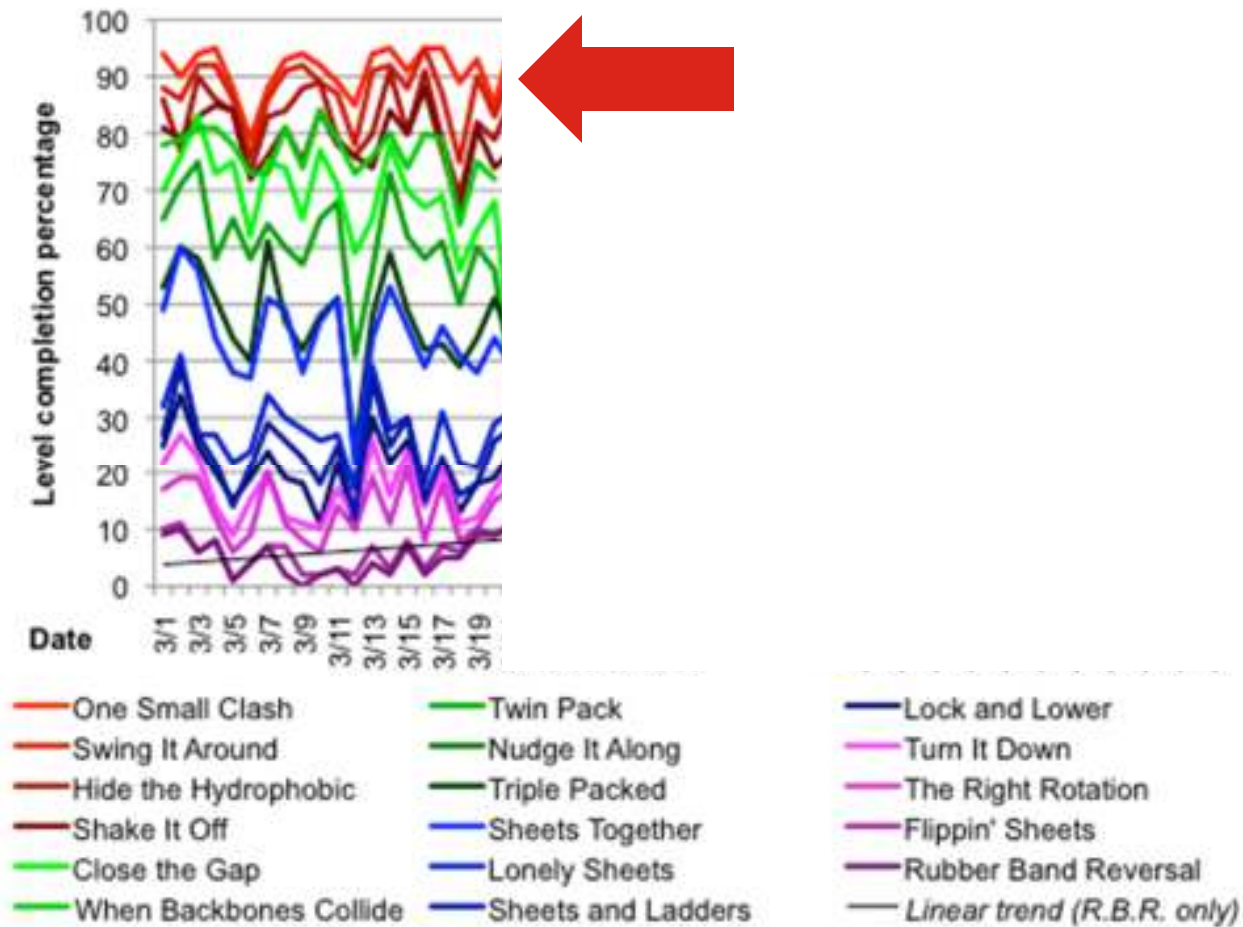
Training

refinement



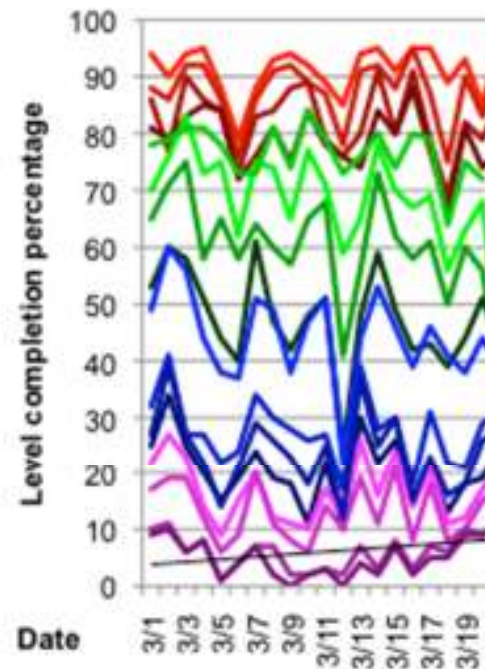
Training

refinement



Training

refinement



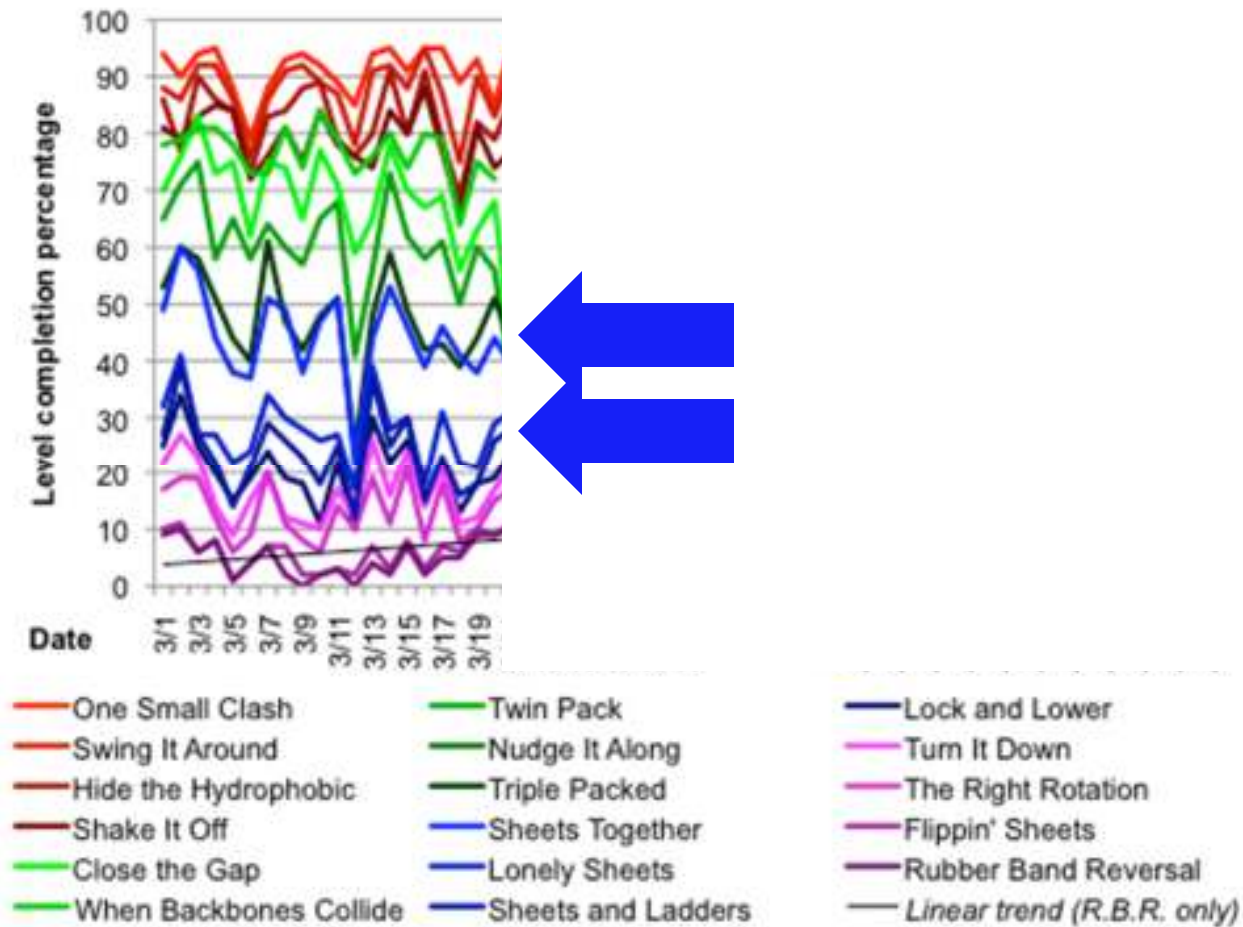
One Small Clash	Twin Pack
Swing It Around	Nudge It Along
Hide the Hydrophobic	Triple Packed
Shake It Off	Sheets Together
Close the Gap	Lonely Sheets
When Backbones Collide	Sheets and Ladders

Lock and Lower
Turn It Down
The Right Rotation
Flippin' Sheets
Rubber Band Reversal
Linear trend (R.B.R. only)

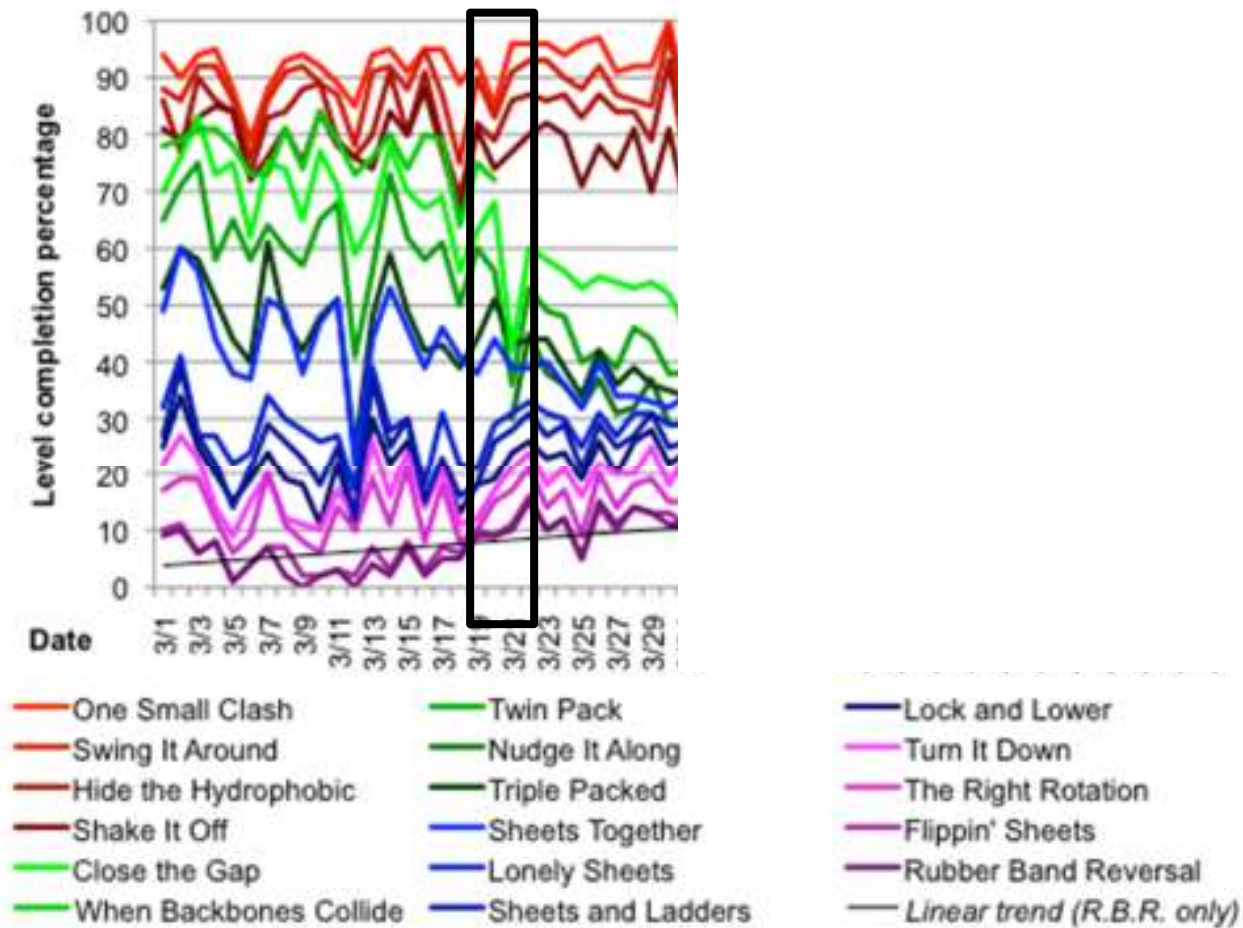


Training

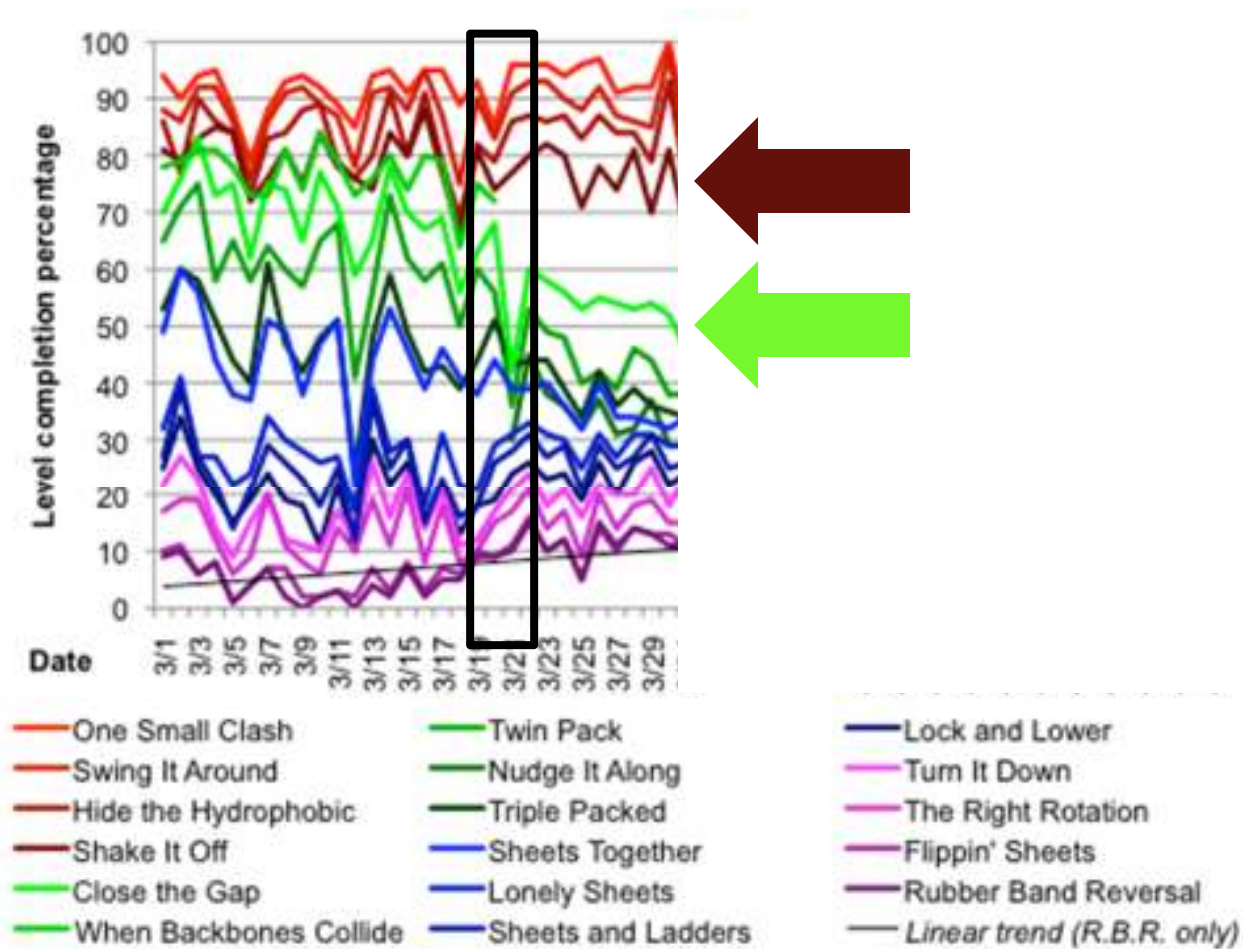
refinement



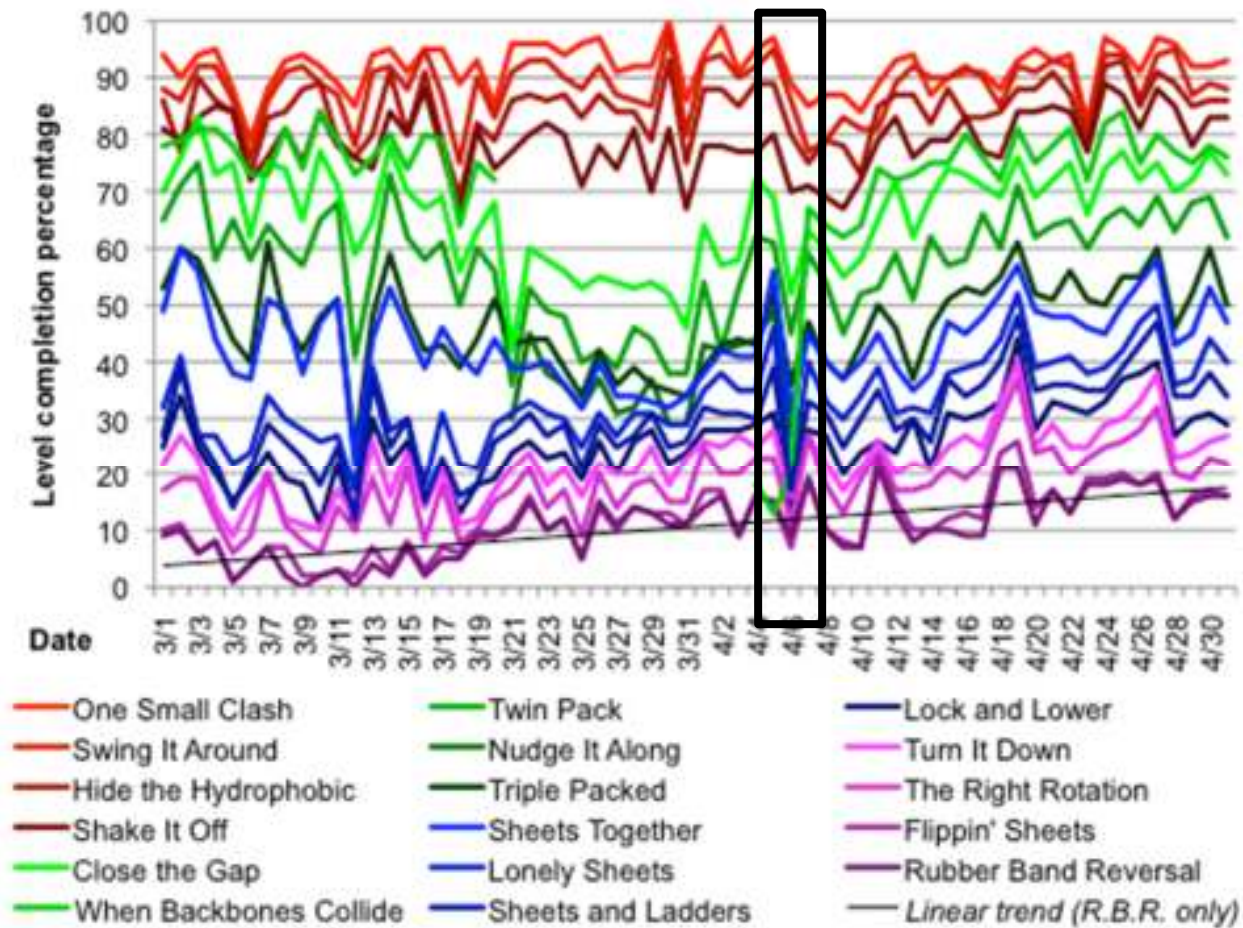
Training refinement



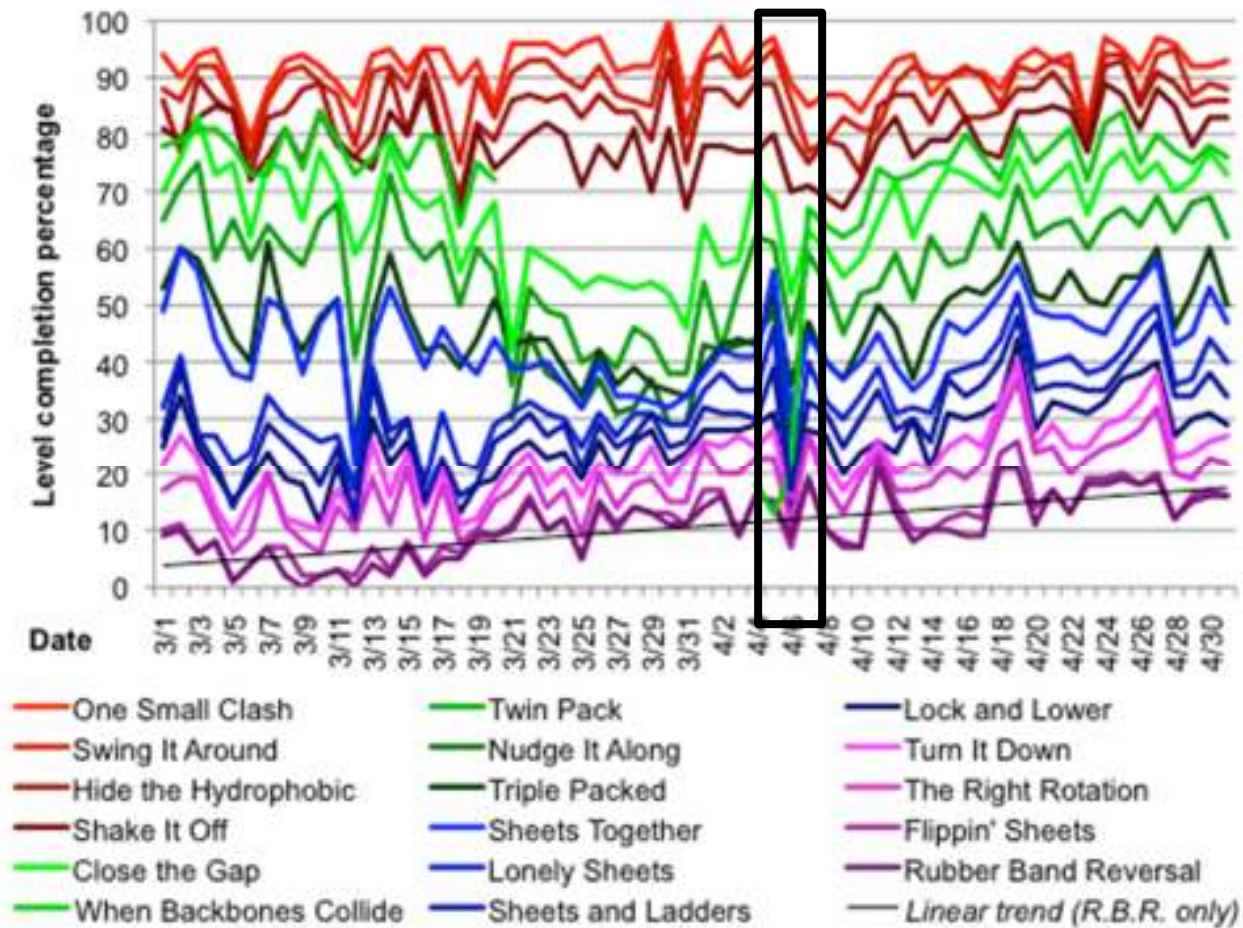
Training refinement

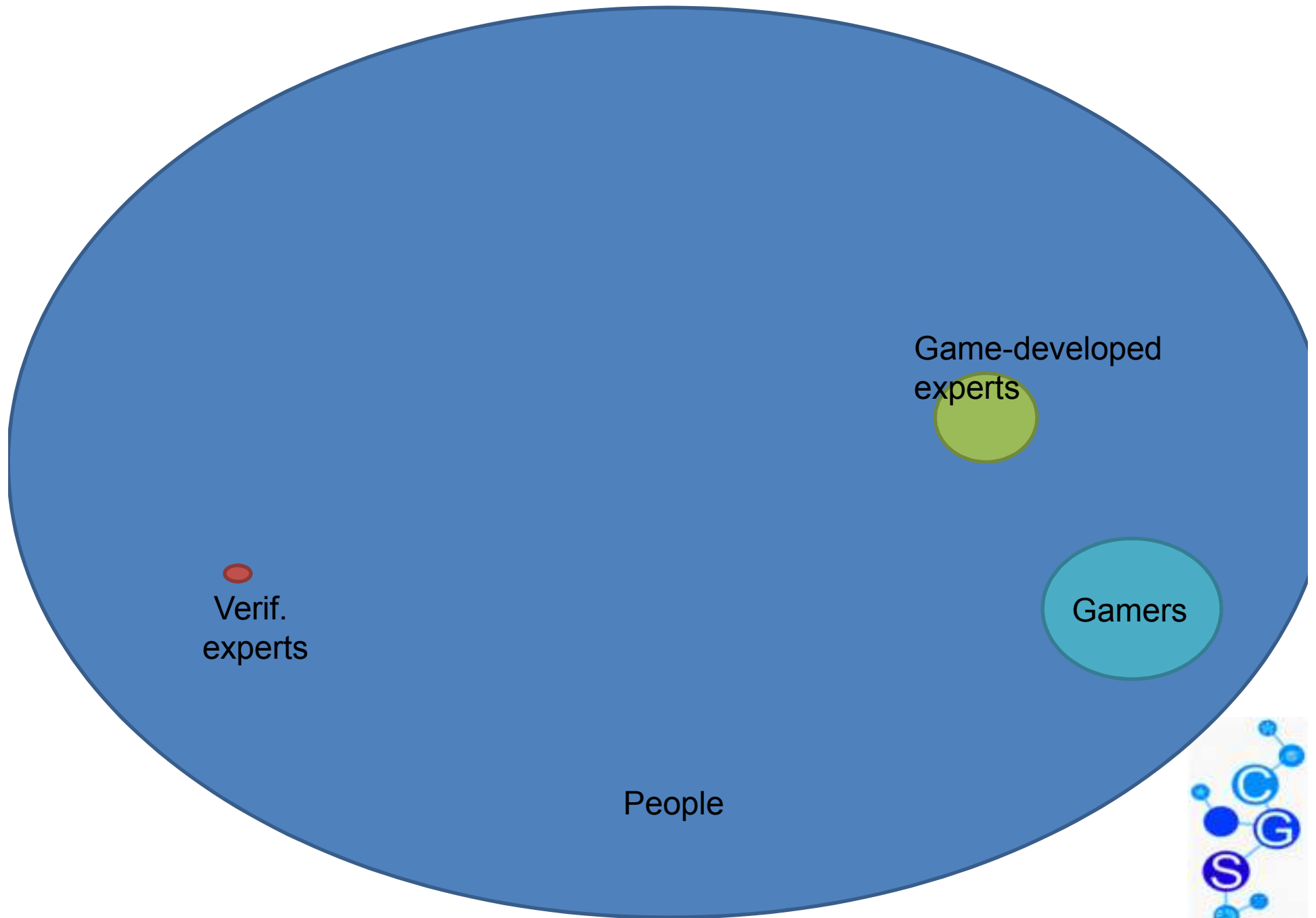


Training refinement



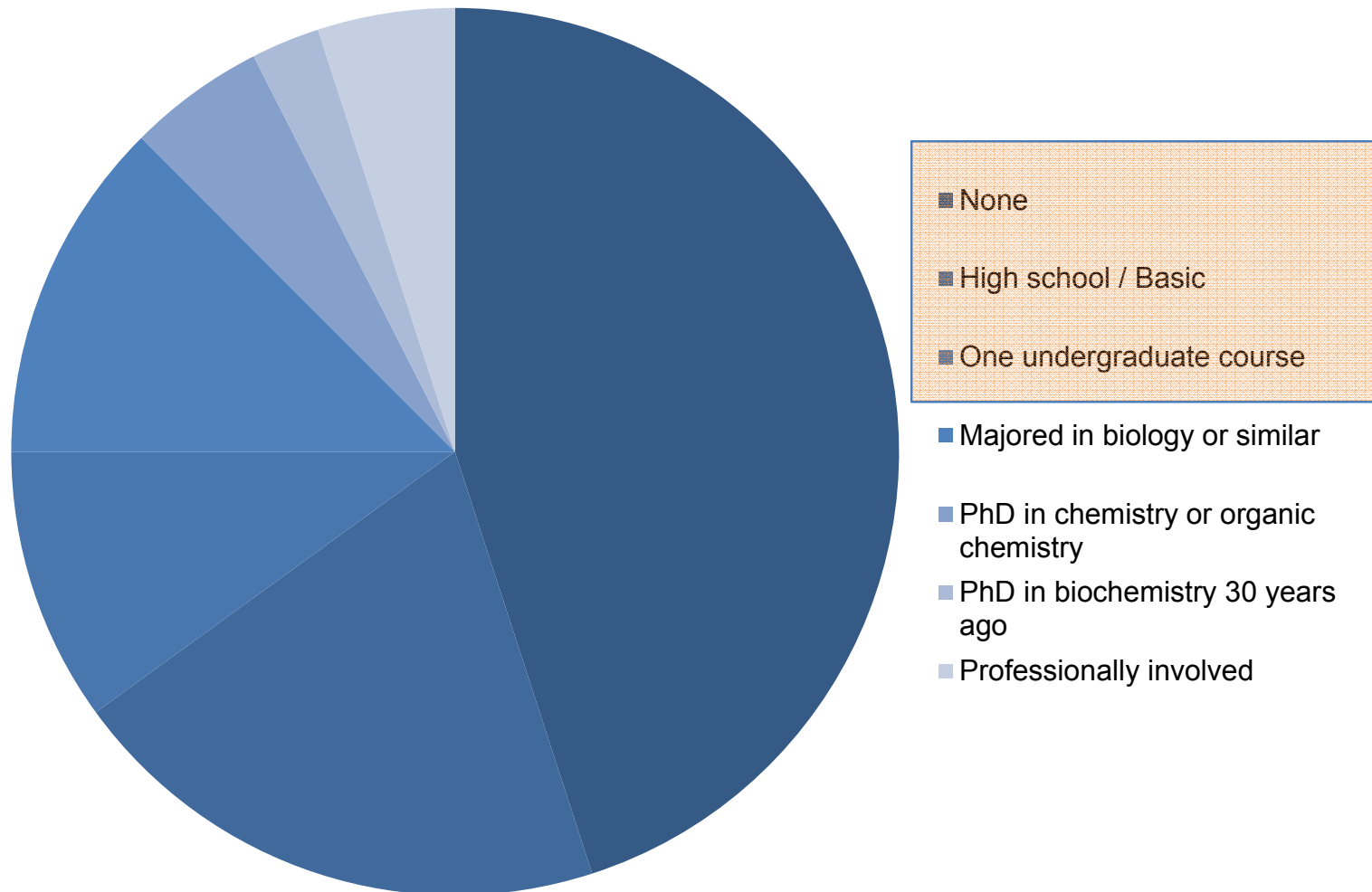
Training refinement



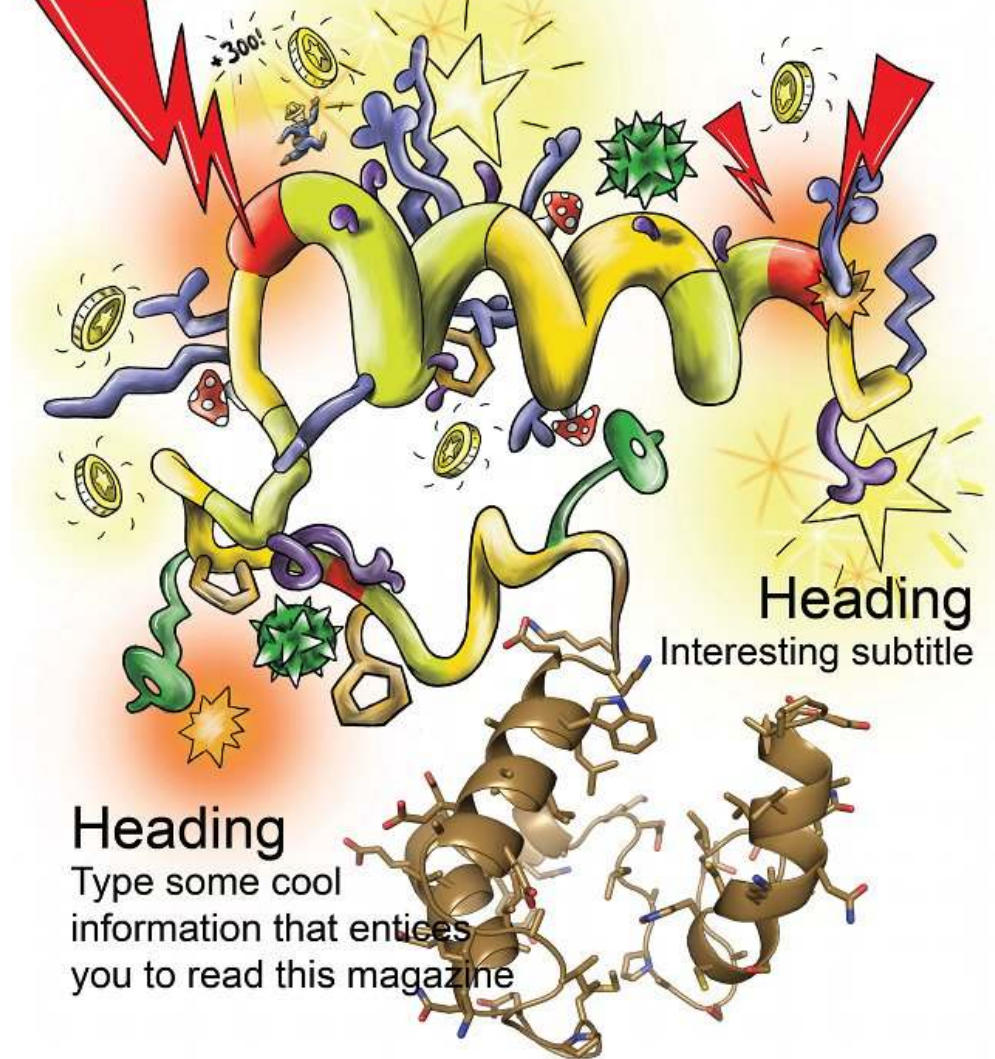


Biochemistry not just for experts...

Prior knowledge of biochemistry

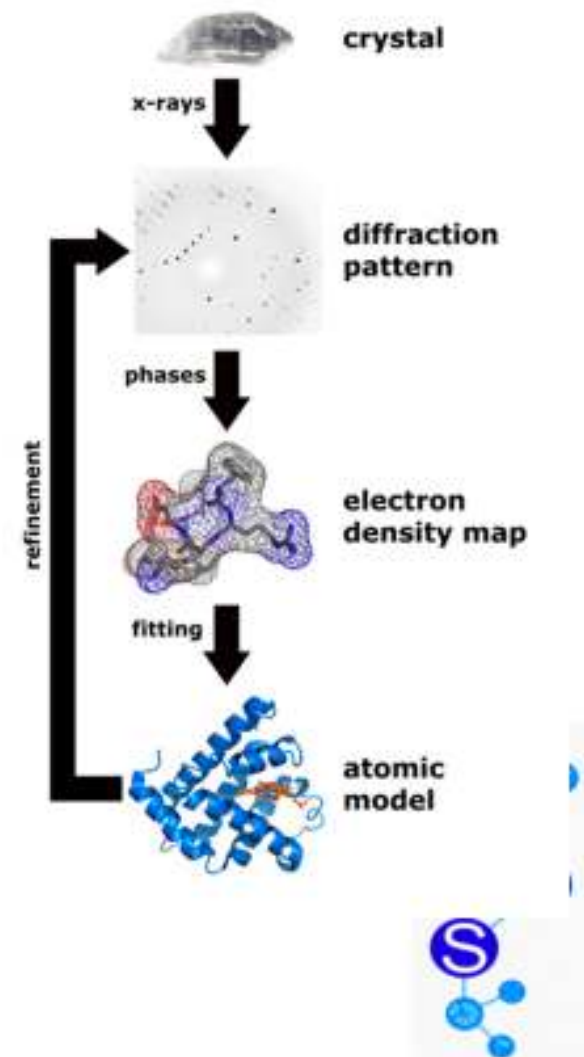


nature



Experimental Structure Solved

- Mason-Pfizer Monkey Virus Retroviral Protease (MPMV PR)
- Plays a role in AIDS in monkeys
- Experimentalists worked on for ~15 years
- Computational methods failed to solve
- Gave to players for 3 weeks



Useful field of view

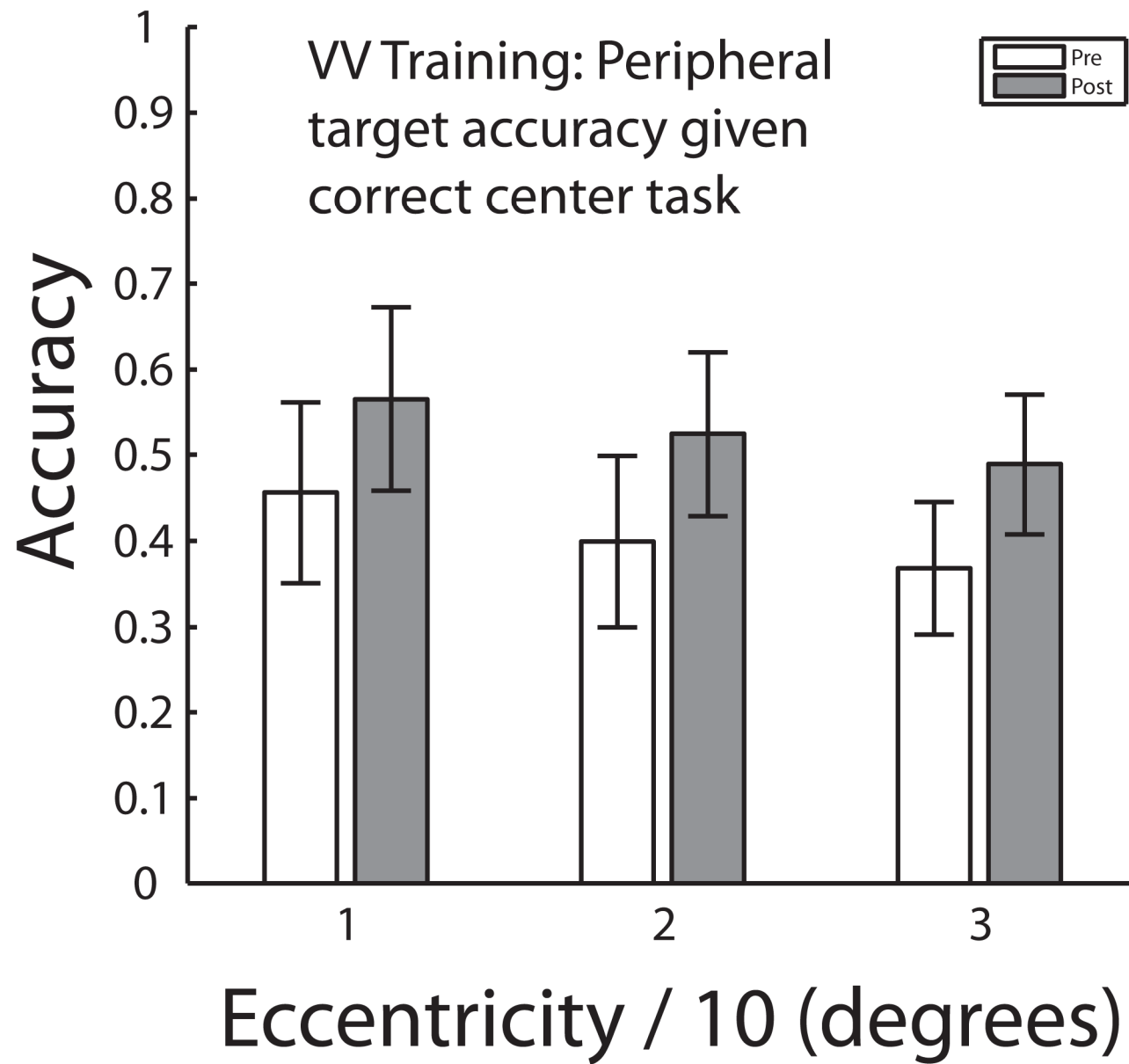
Can low-level visual cognition be improved through game play?

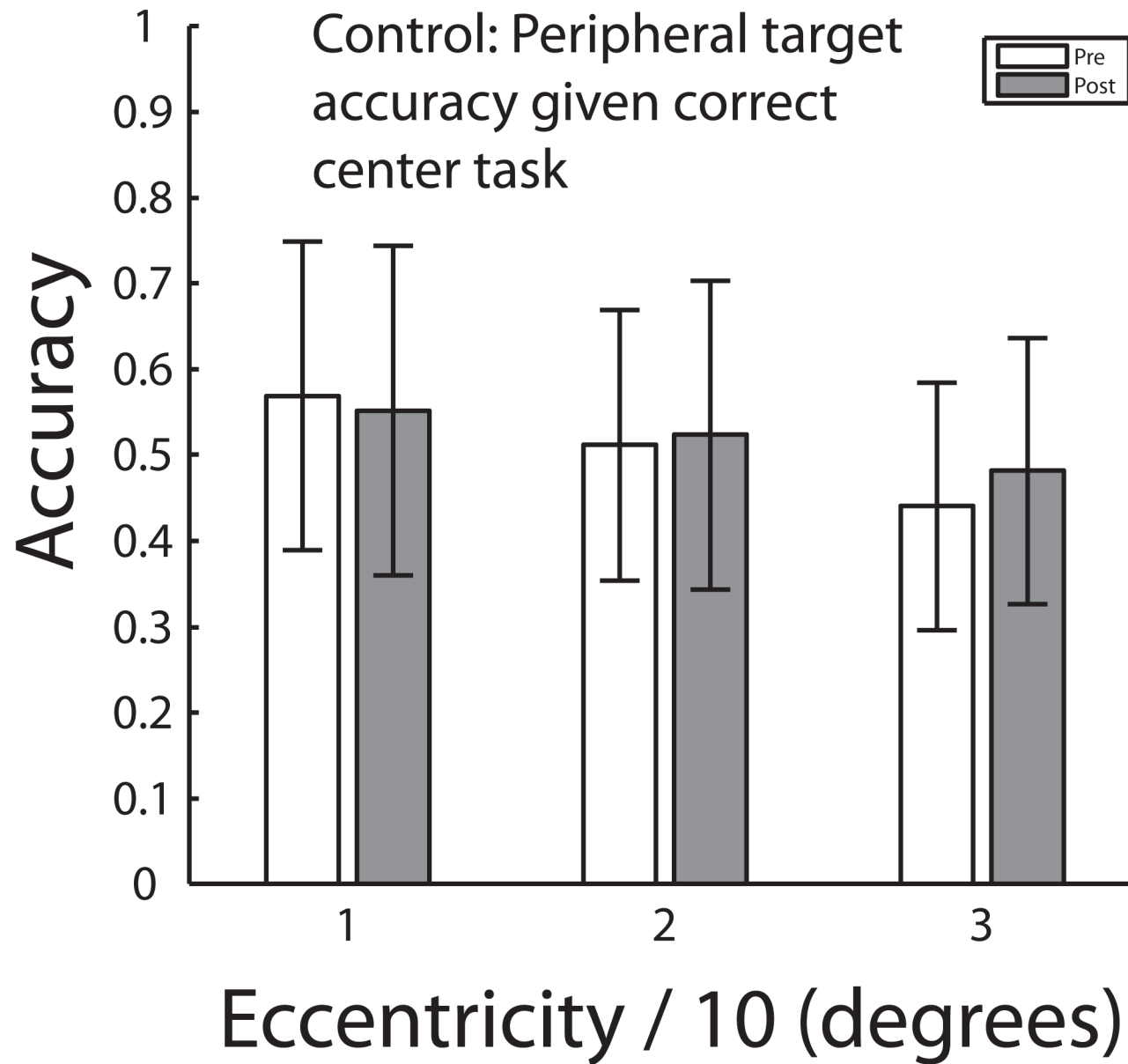


Mech. Turk Incentive Optimization

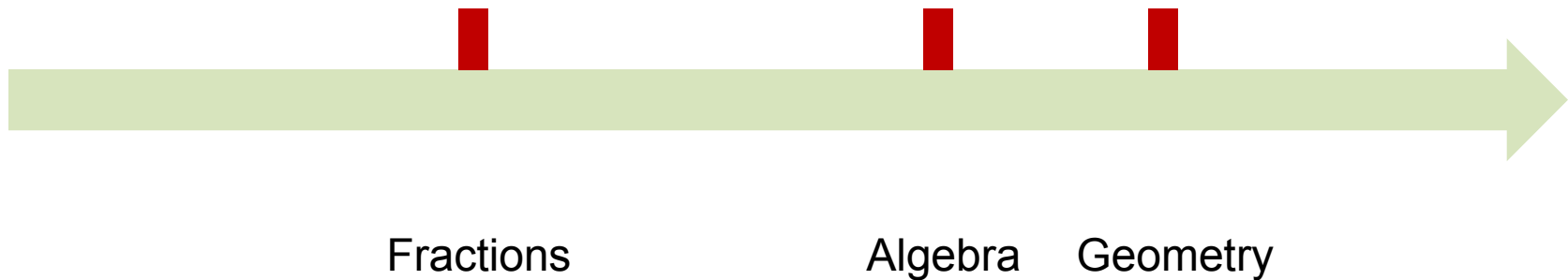
\$1 → \$0.5 → \$.03 → \$0.01 → \$0







Math Bottlenecks



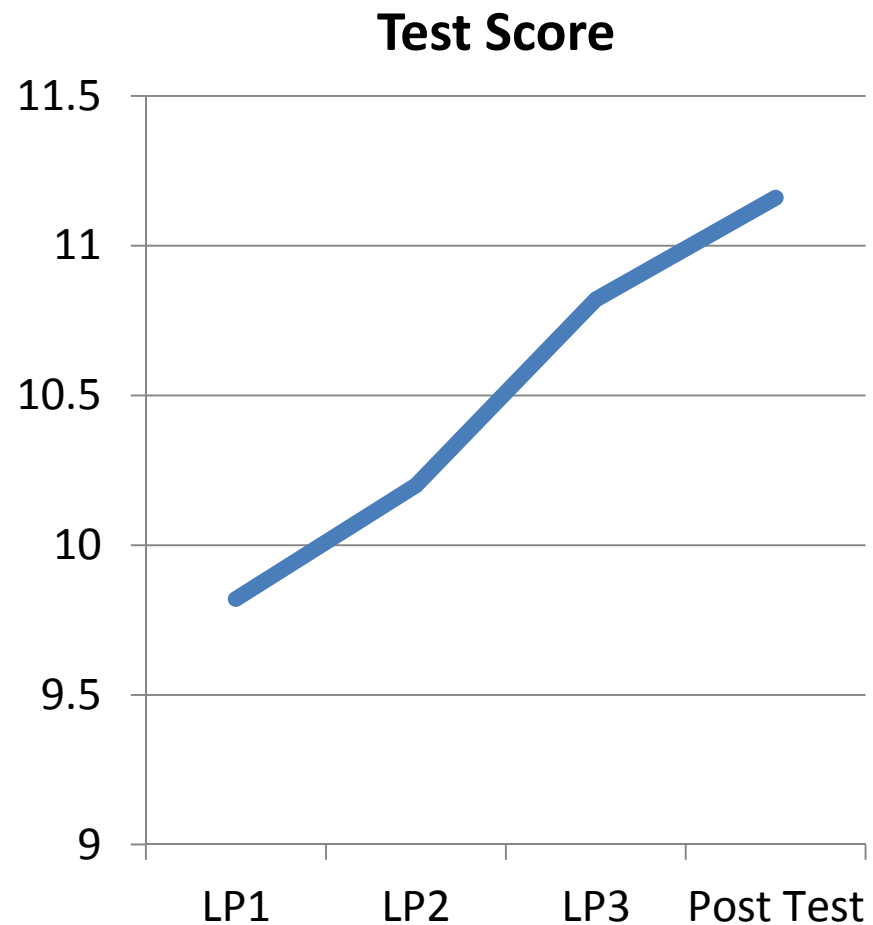
“Difficulty with fractions... is **pervasive** and is a **major obstacle to further progress** in mathematics.”

- US National Mathematics Advisory Panel final report, 2006, 2008



Repeated Gameplay Produces Consistent Improvement

- 4,000 3rd Graders
- Three weekly level packs
- Pretests integrated into gameplay



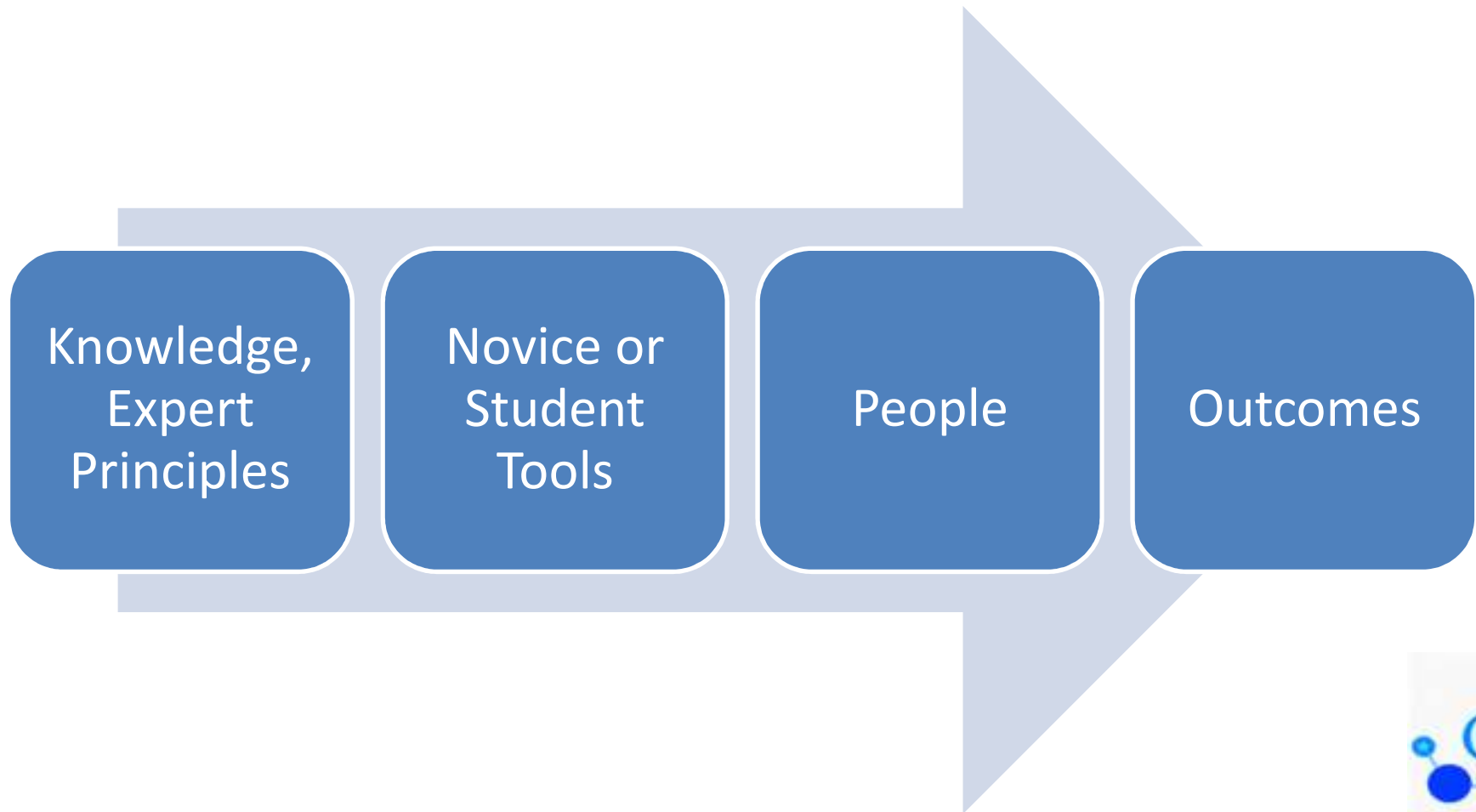
Novice to Experts



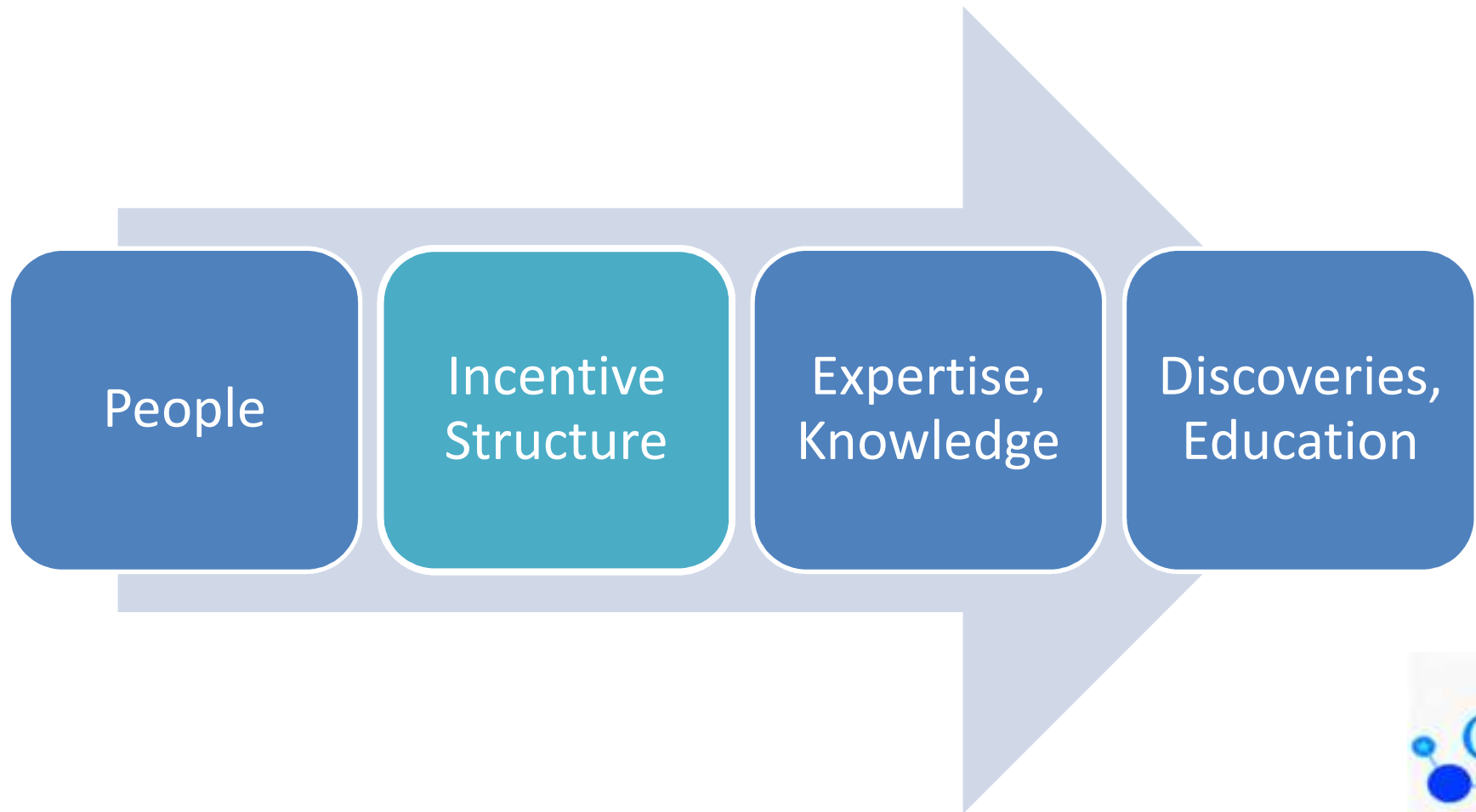
In each case,
Data-driven evolution
with large number of players is
1 to 3 times as long as initial development

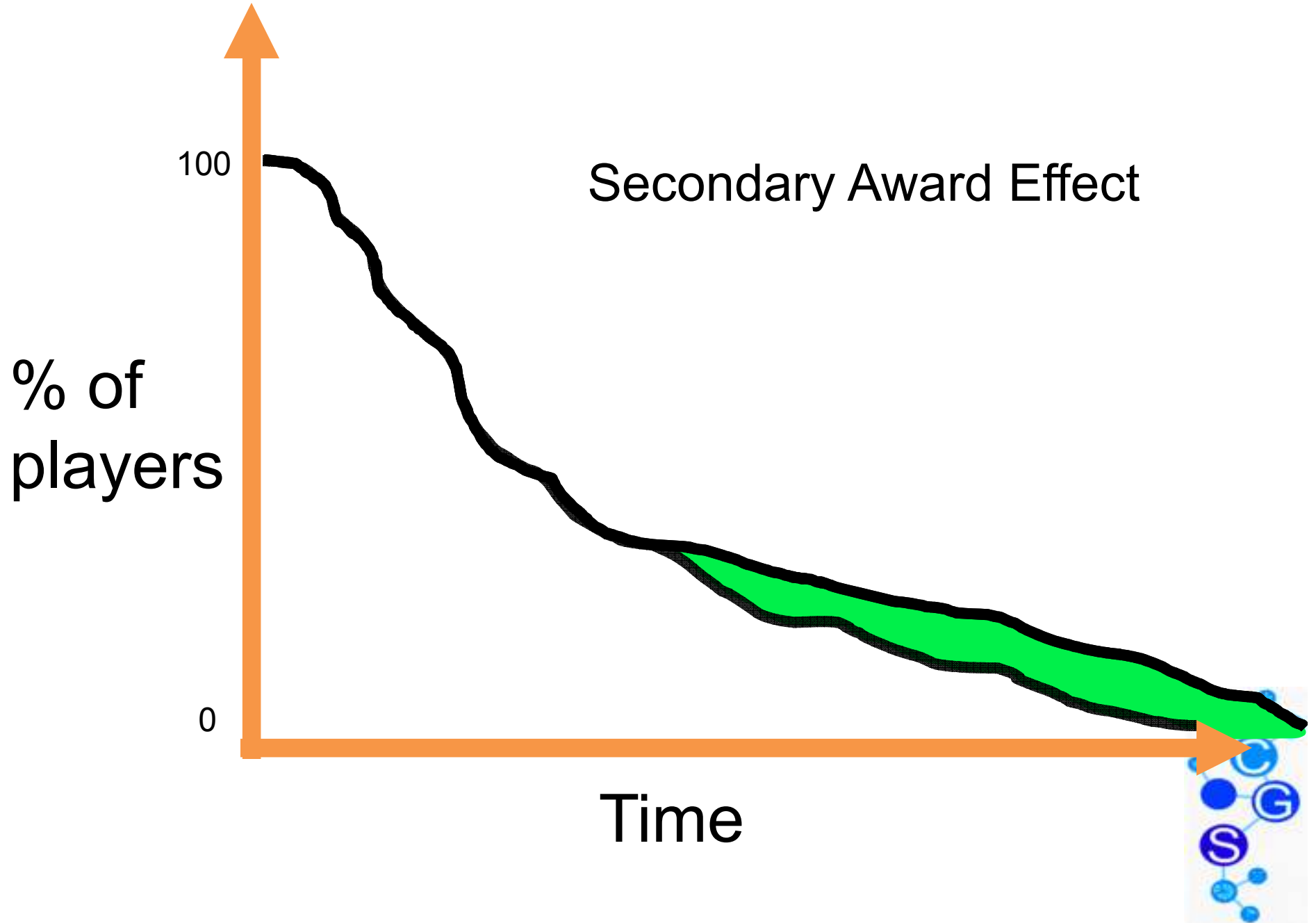


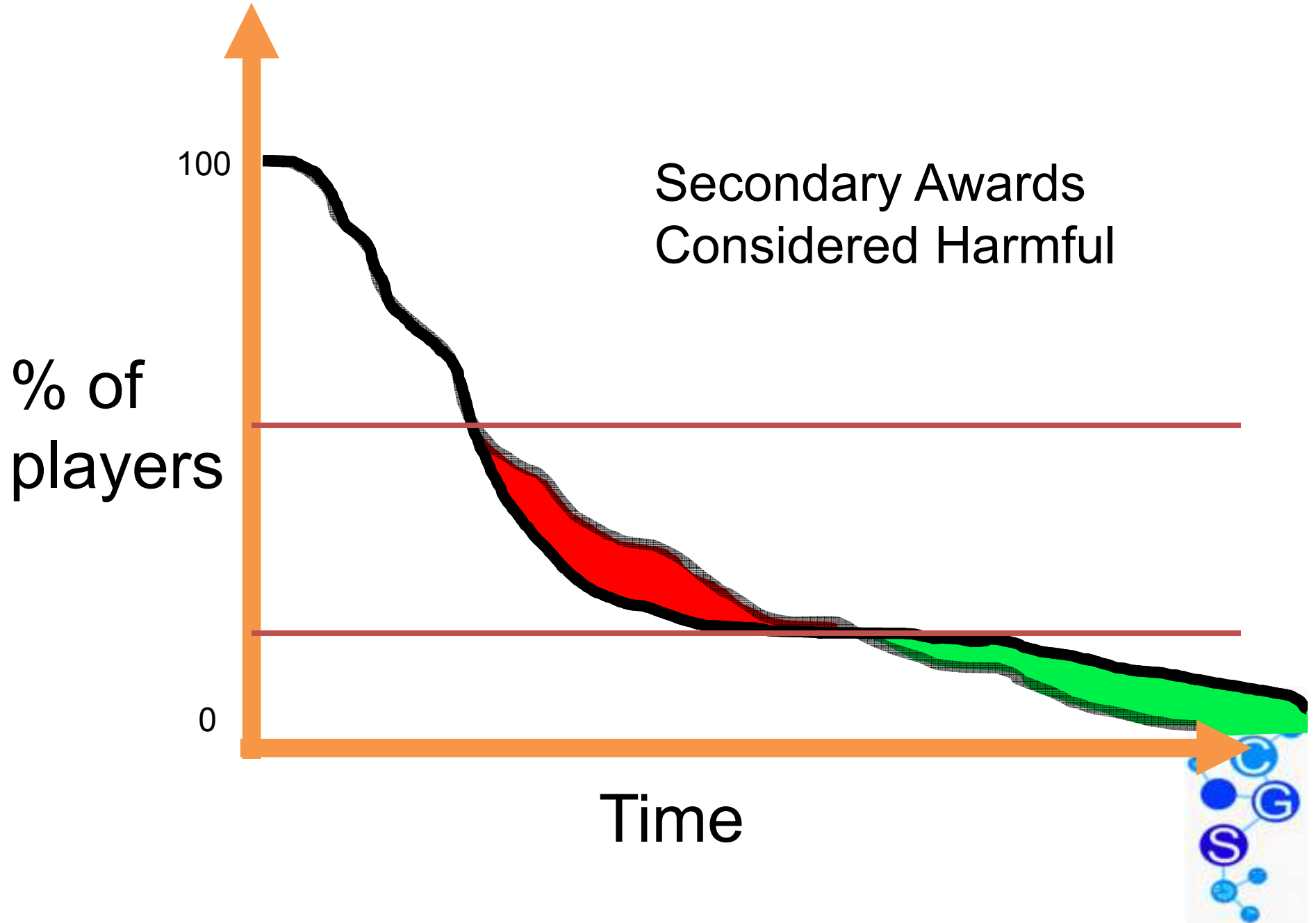
Standard trickle down approach



Incentivized Expert Creation



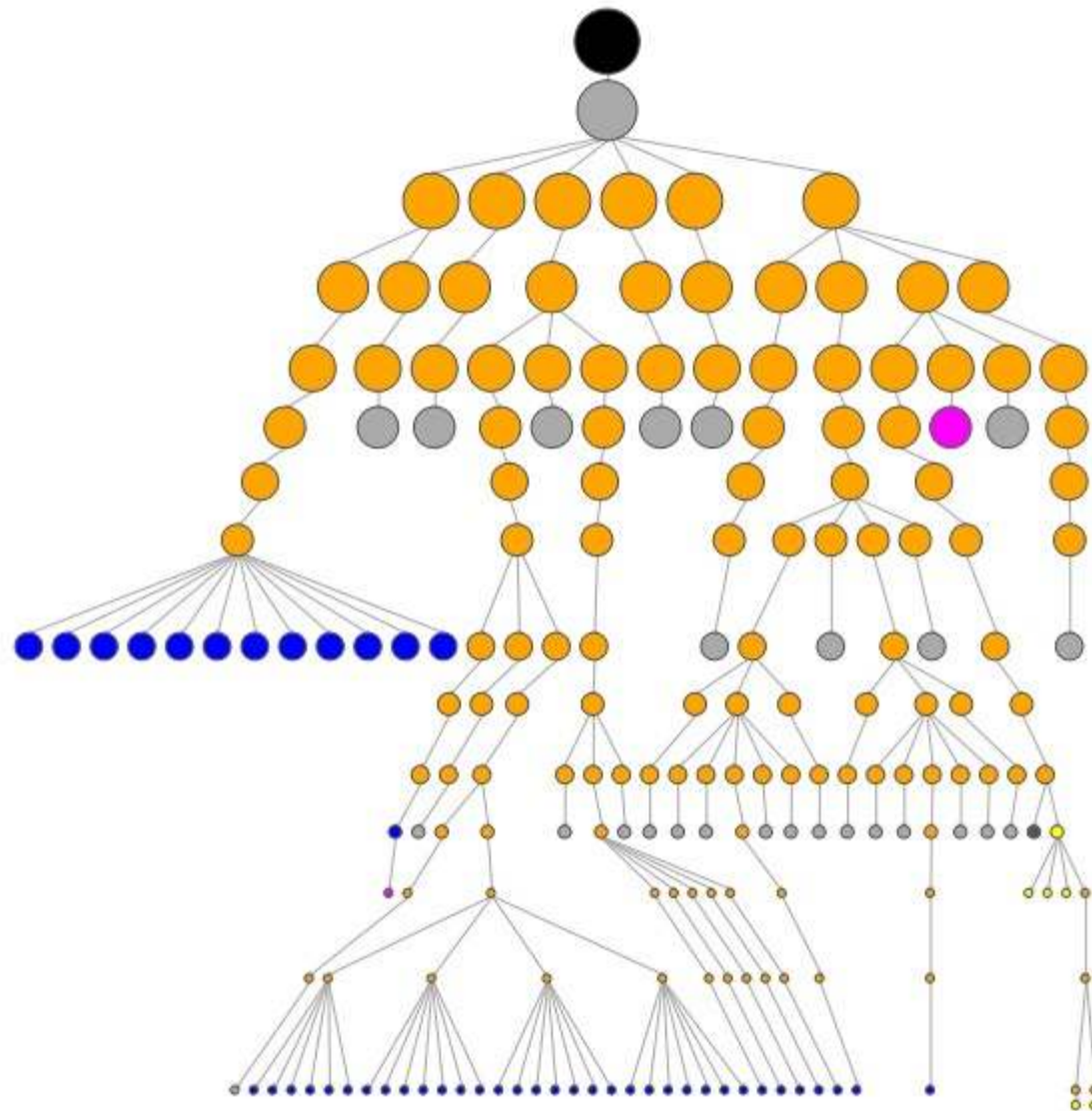




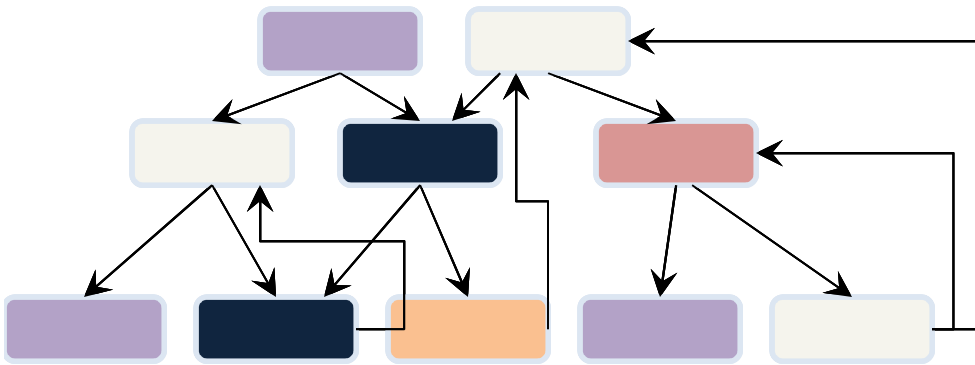
Extrinsic Motivation: short term effect

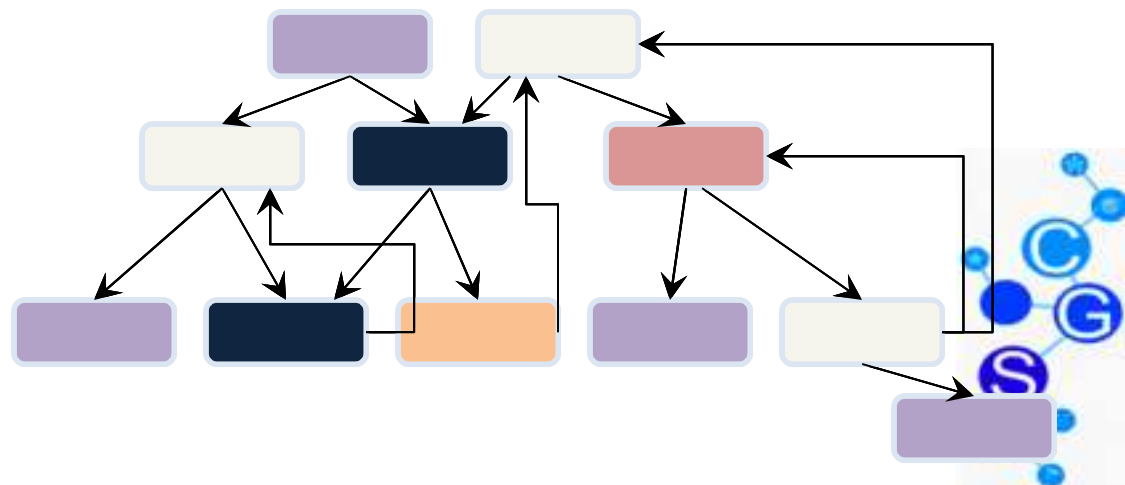


Hierarchical randomized trials



In-game assessment and intelligent tutor refinement





Level Adaptation

- Adapt to maximize long term engagement
- Optimize for persistence
- Expand at the boundary of understanding



Playtracer Query Tool

```
put_down_wrong_splitter(Action, Trace, Level, Player) :-  
    is_action(Action, Trace, Level, Player),  
    is_bad_splitter_on_board(Splitter, Level),  
    happens(Action, dropped_piece(Splitter)),
```

- Uses logging data to generate facts (e.g., happens)
- Leverages complex query language to encode game-specific logic in rules (e.g., is_bad_splitter_on_board)
- Backed by database system that allows these queries to be run on a large amount data



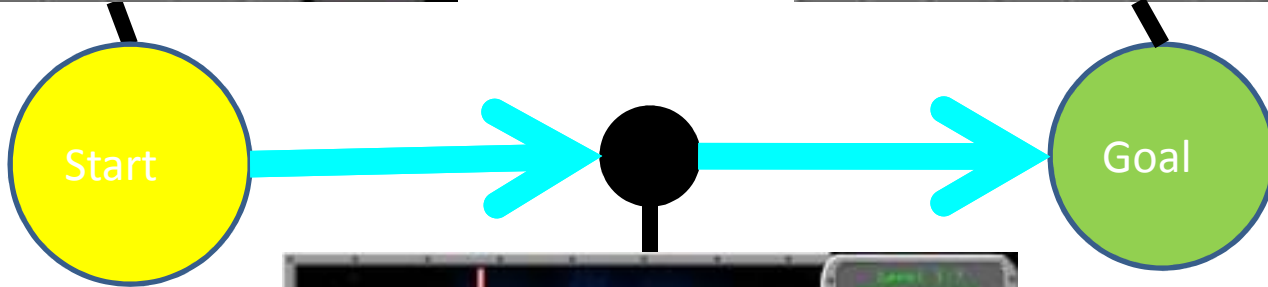
Writing Rules

```
% holds if the user dropped a 2-splitter Piece on Action
did_drop_2splitter(Action, Piece) :-
    happens(Action, drop(Piece, _)),
    action(Action, Trace),
    trace(Trace, _, Level),
    holds(Level, piece_type(Piece, splitter2)).

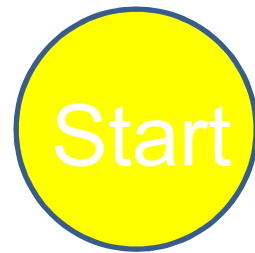
% action A2 happens after A1 in the same trace
% assumes next_action is correctly defined
later_action(A1, A2) :- next_action(A1, A2).
later_action(A1, A3) :-
    next_action(A1, A2),
    later_action(A2, A3).

% holds if the user dropped a 2-splitter Piece on A1
% but then picked it up later on A2
dropped_2splitter_then_picked_it_up(A1, A2, Piece) :-
    did_drop_2splitter(A1, Piece),
    happens(A2, pickup(Piece)),
    later_action(A1, A2).
```

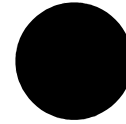
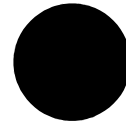
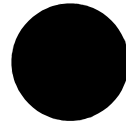
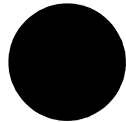
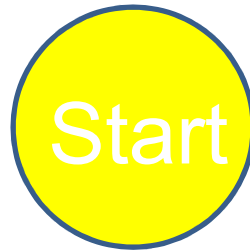




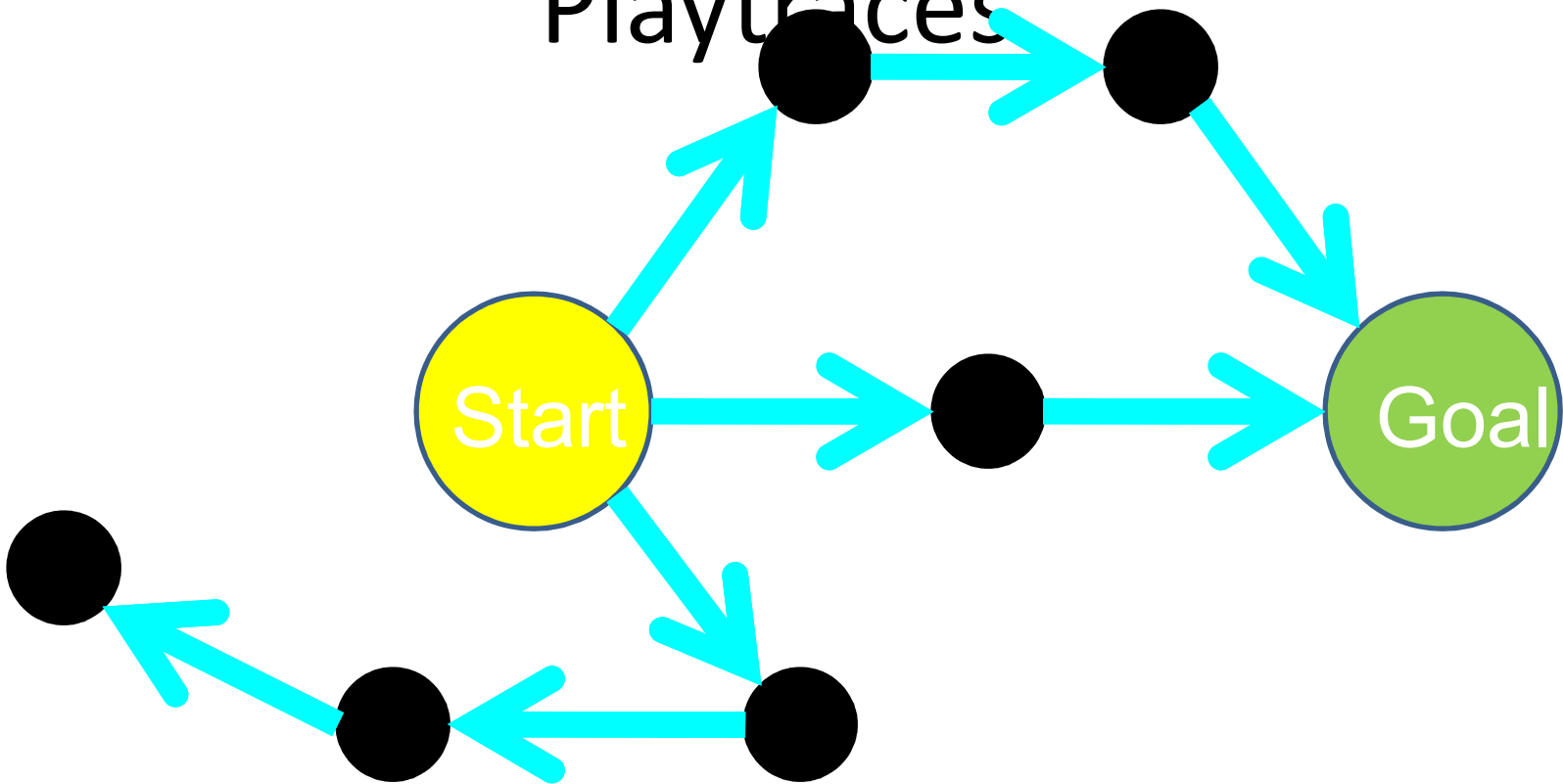
“Playtraces”

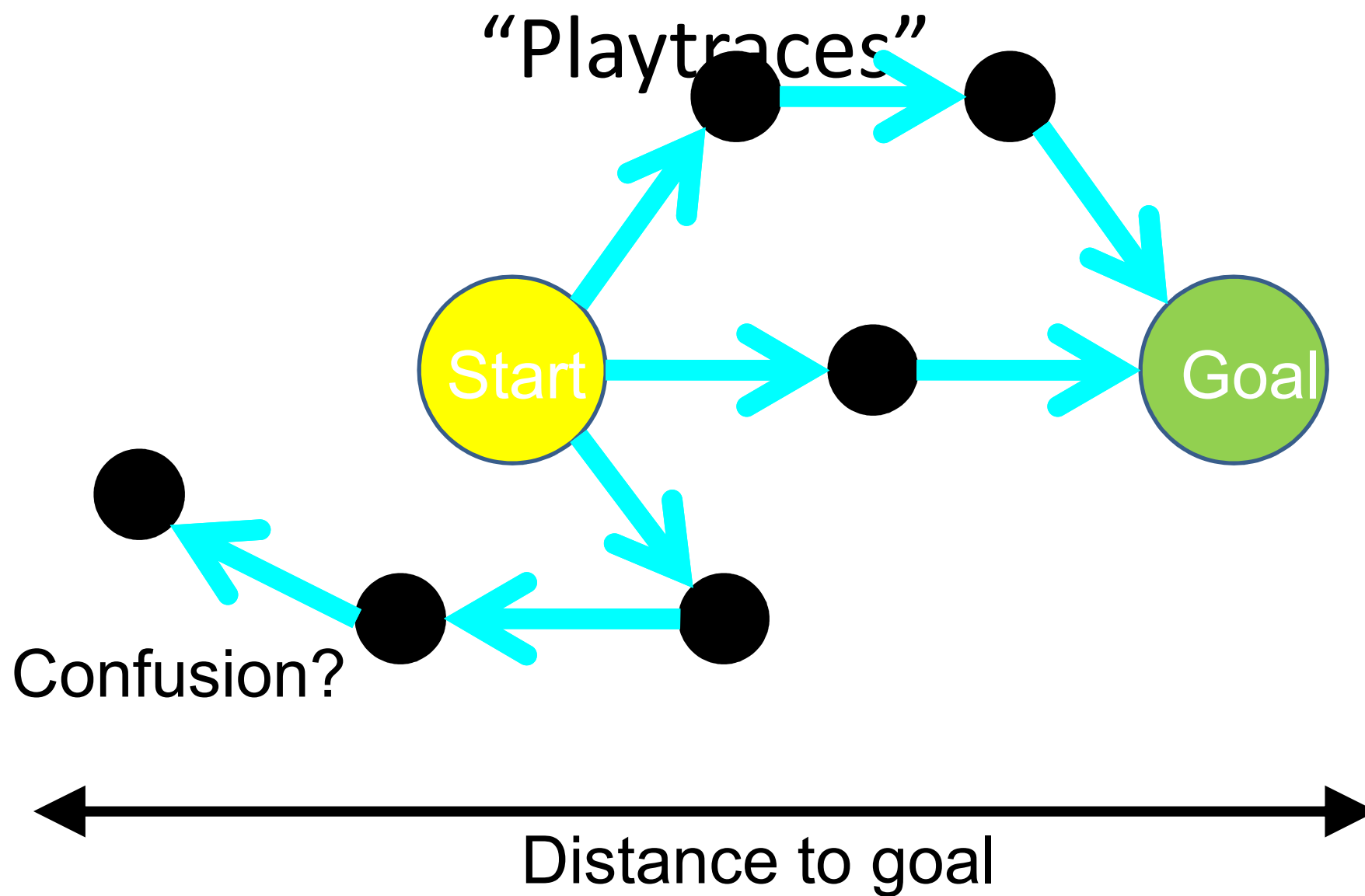


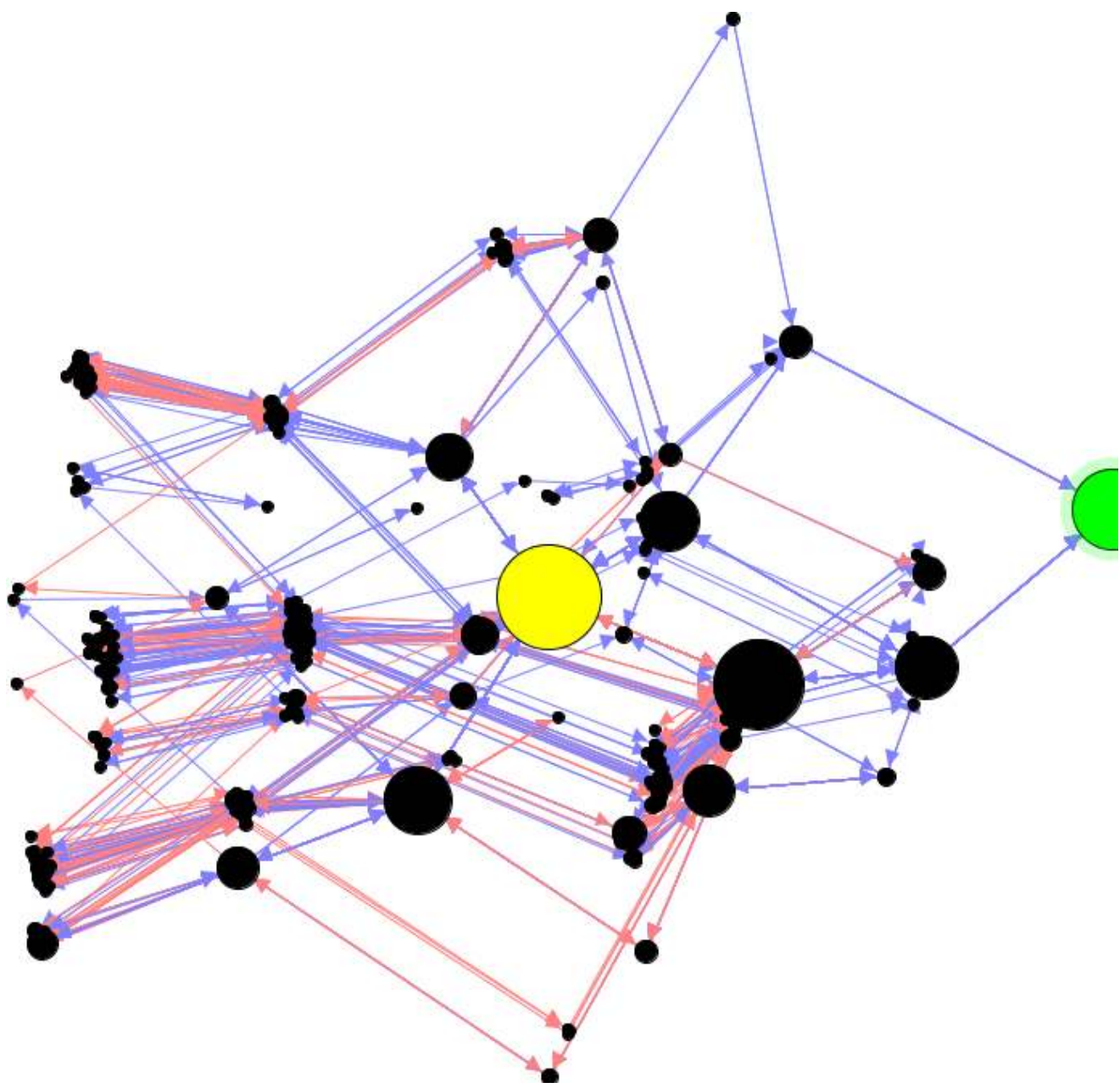
“Playtraces”

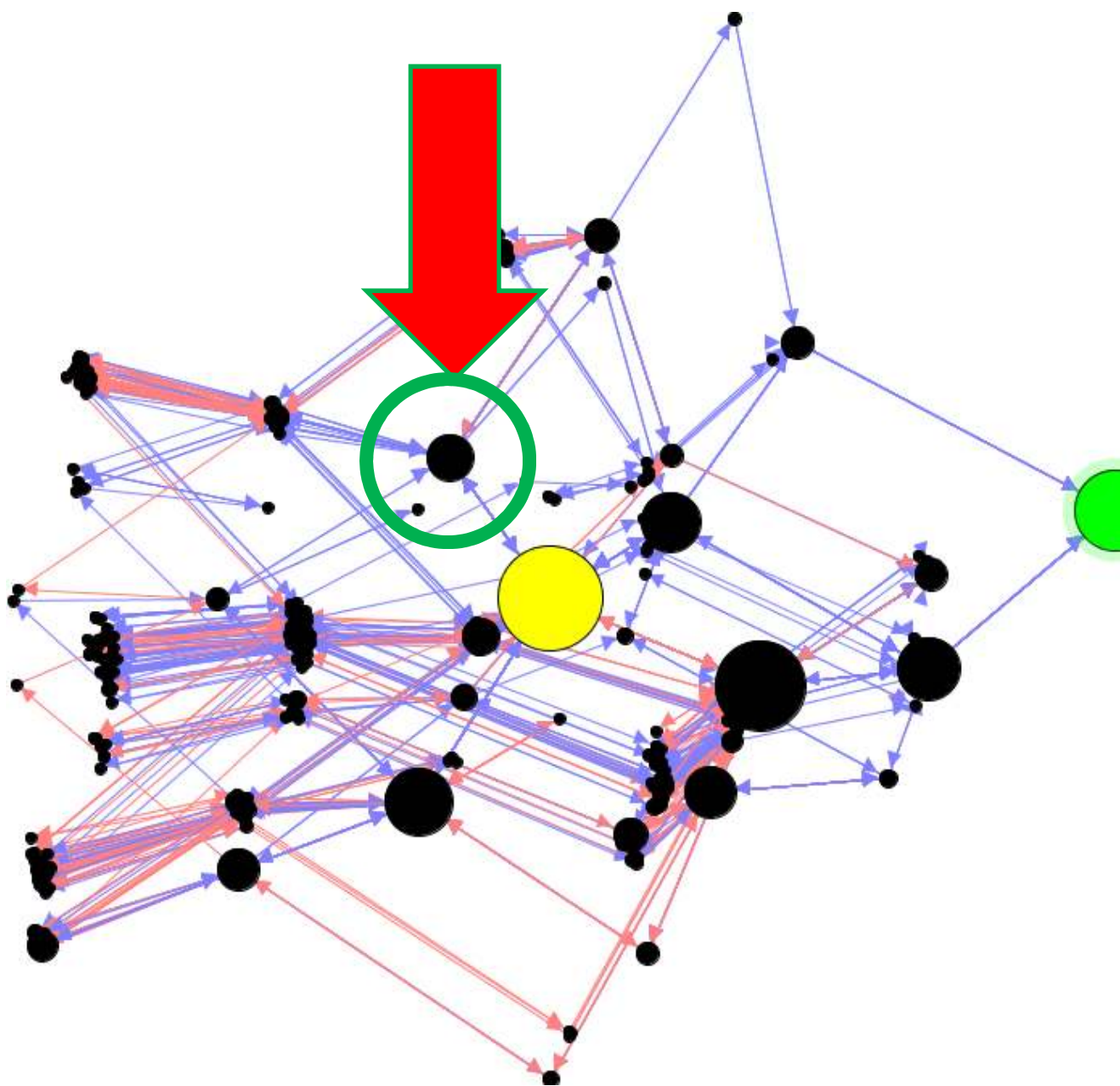


“Playtraces”

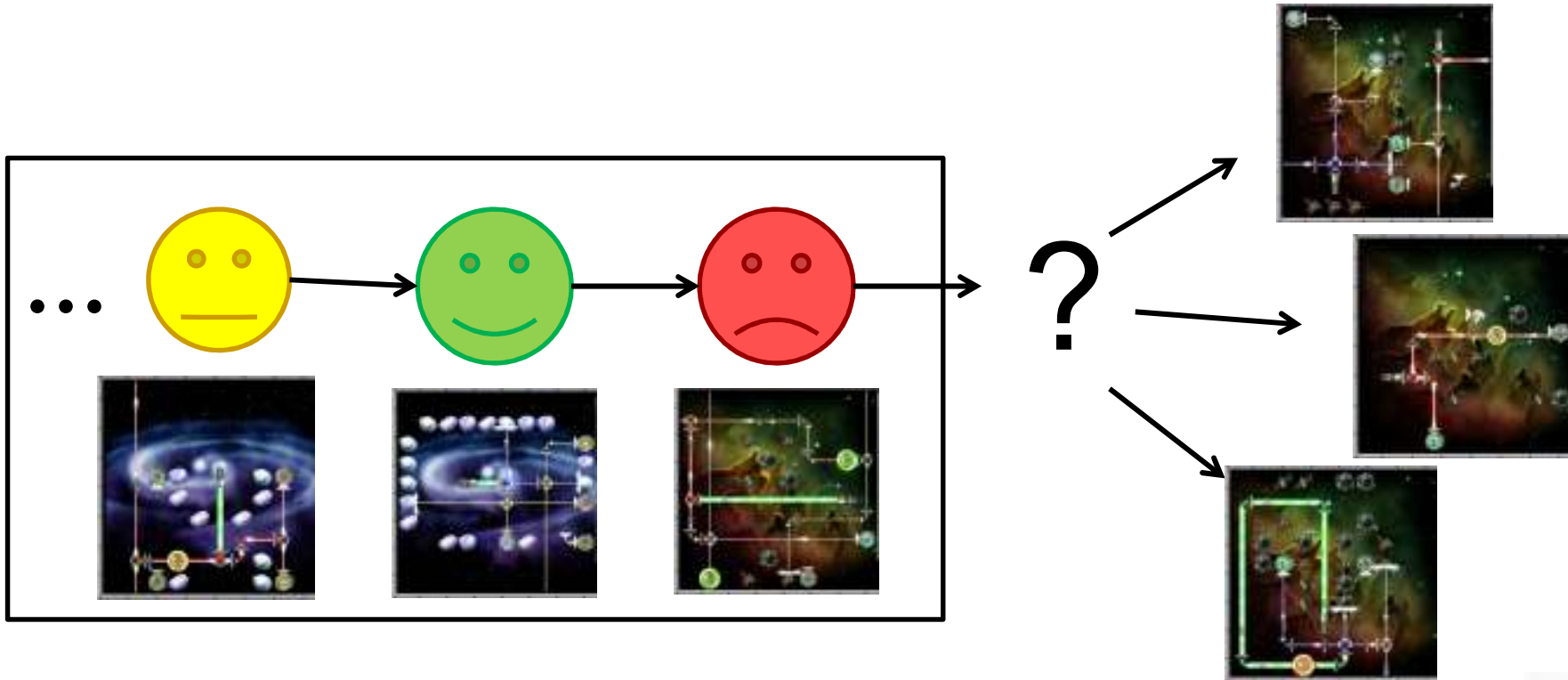






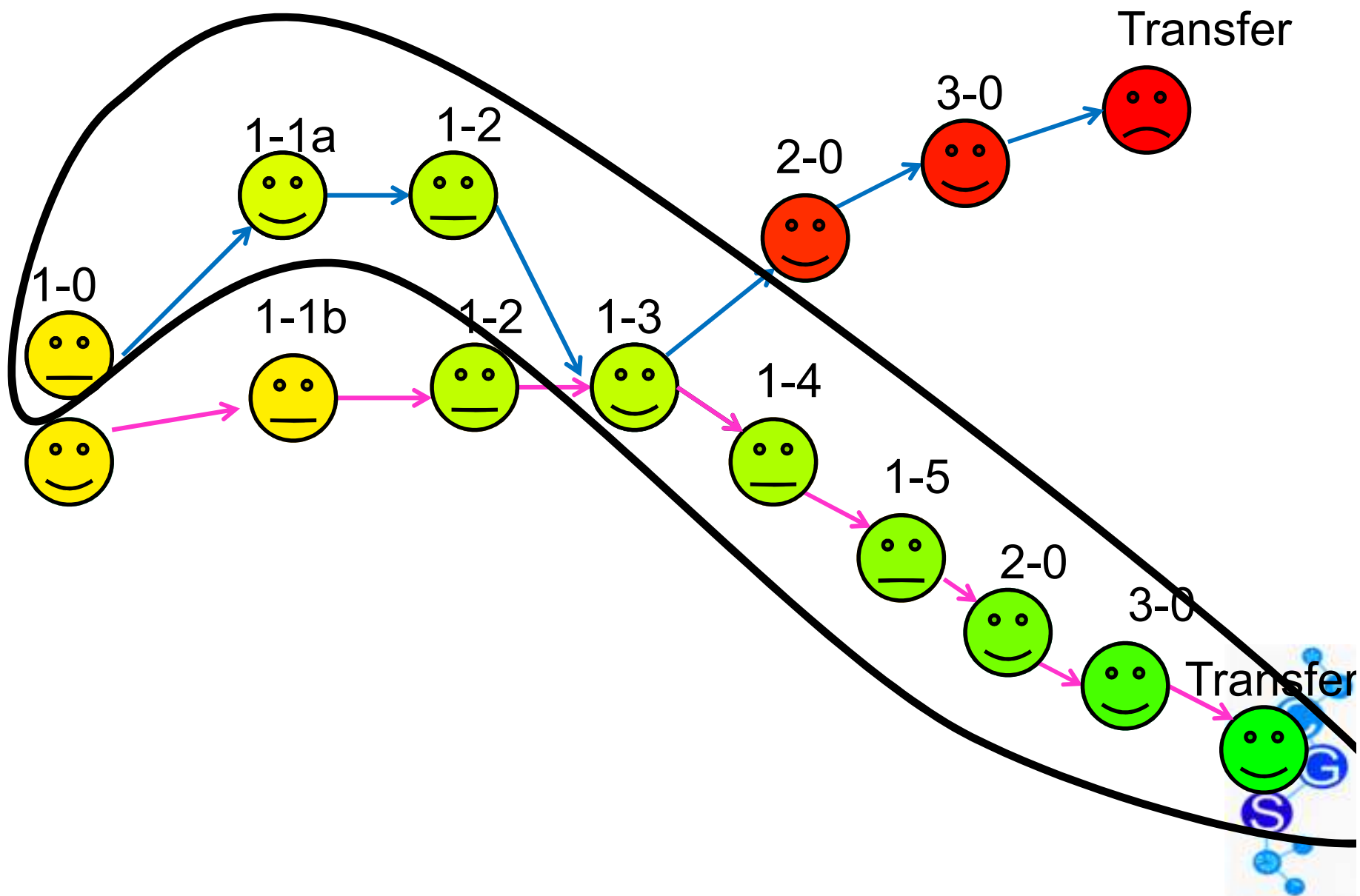


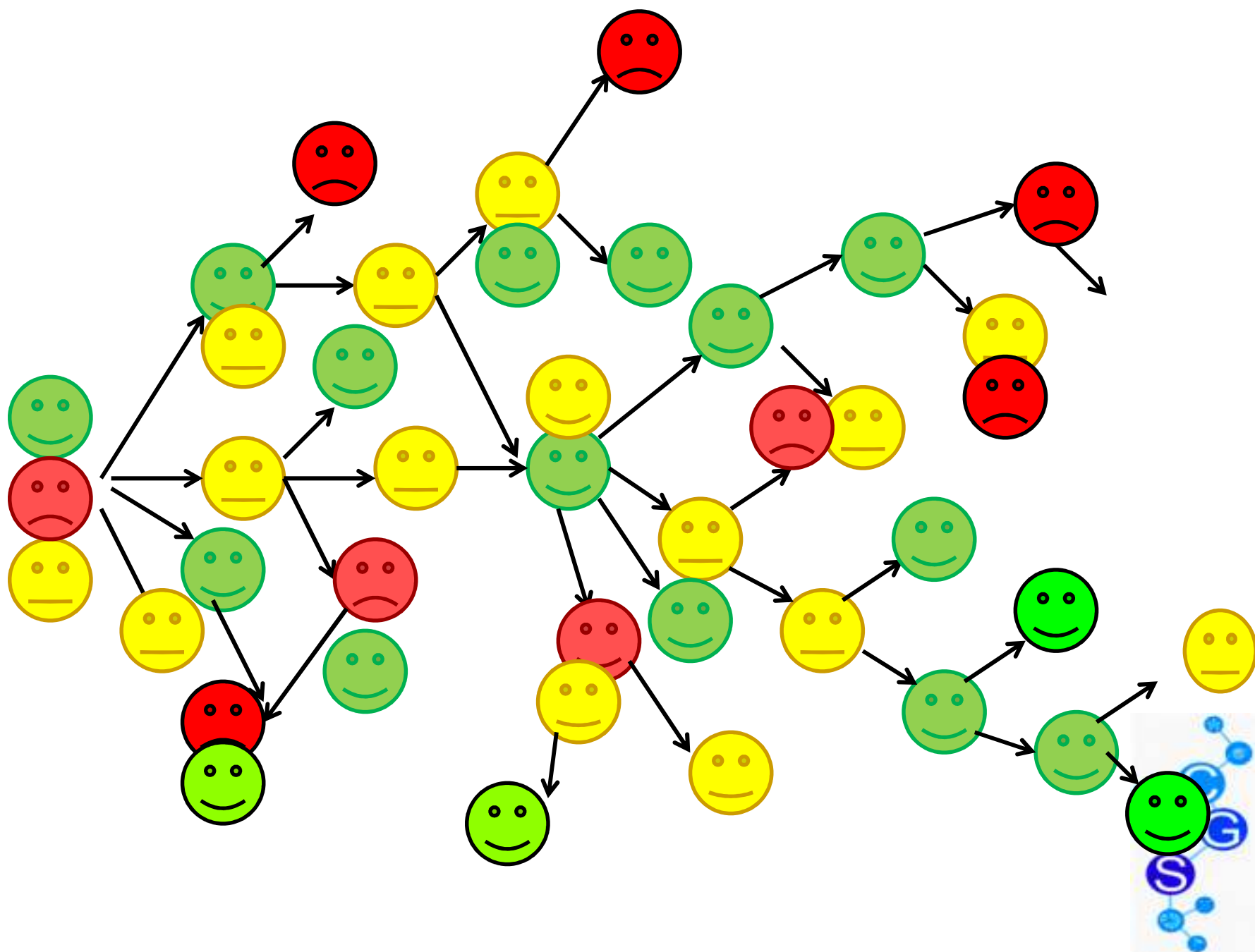
Reinforcement Learning problem



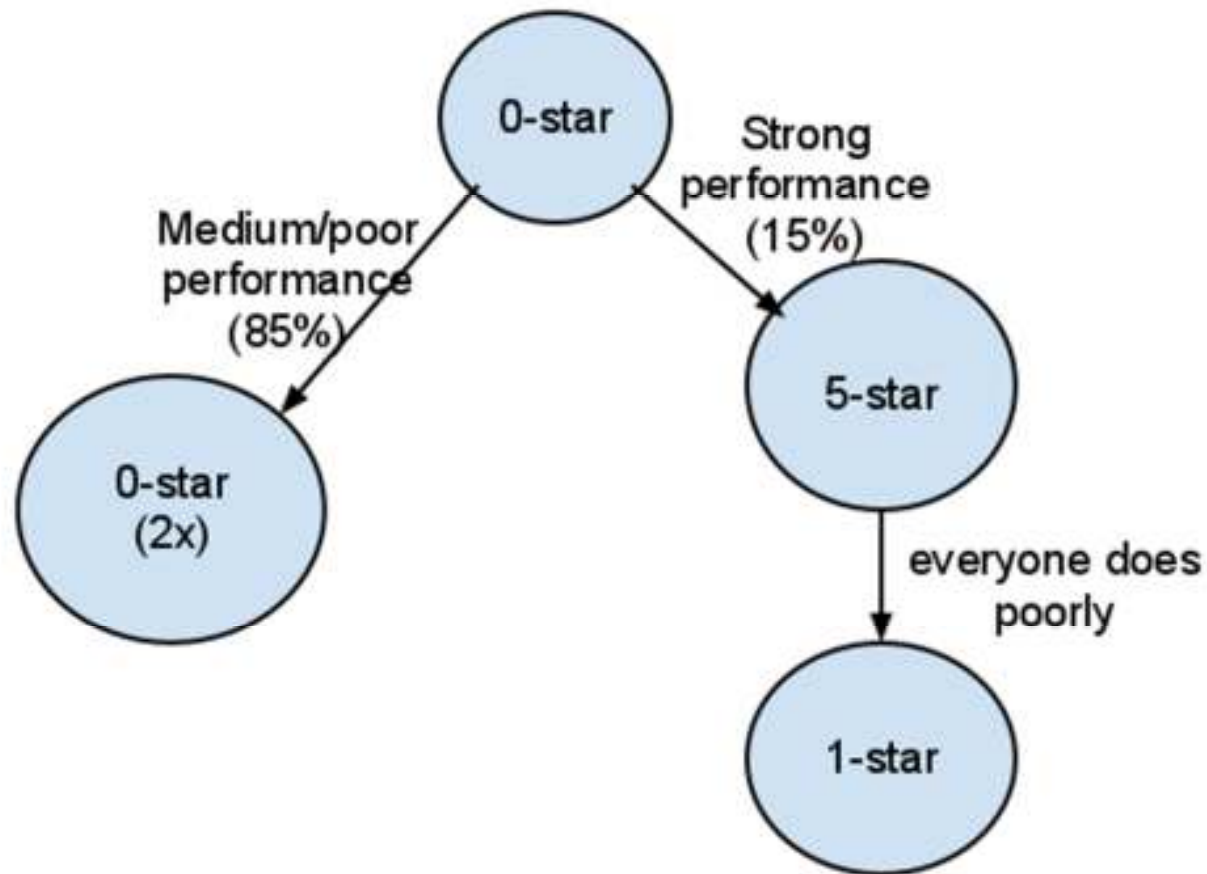
Goal: Maximize student's learning & engagement





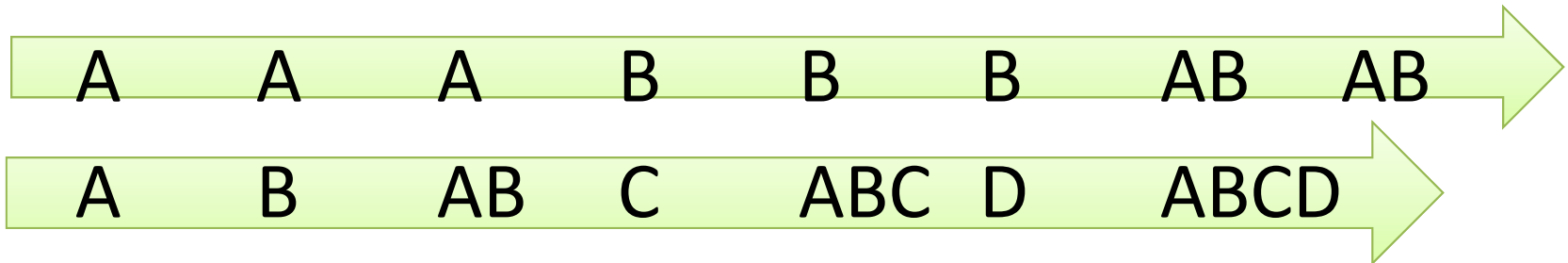


Early Experiment

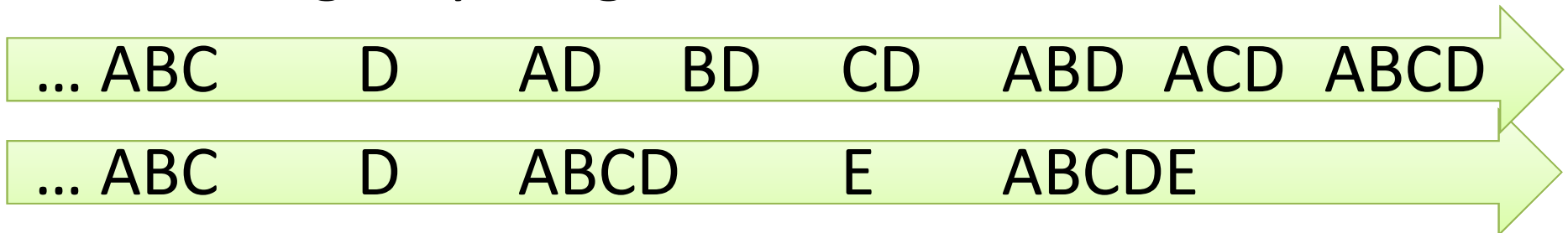


Key RL experiments

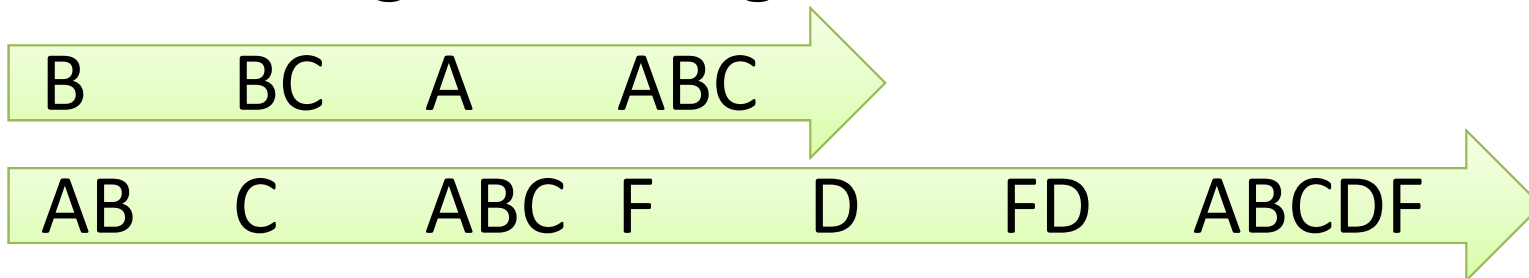
- Dwell Time (Time on Task)



- Challenge layering



- Challenge Ordering



Key RL experiments

- Optimal hinting strategies
- Persistence and tenacity
- Long-term effects on domains
- Self-identification



Effects of hinting depth

Two $\frac{1}{3}$ Ships:

- (1) "Try this piece" <point to the 3-splitter>
- (2) "To make $\frac{1}{3}$, split the laser in three"
- (3) "How much power do the ships need?"

Make $\frac{1}{4}$:

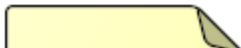
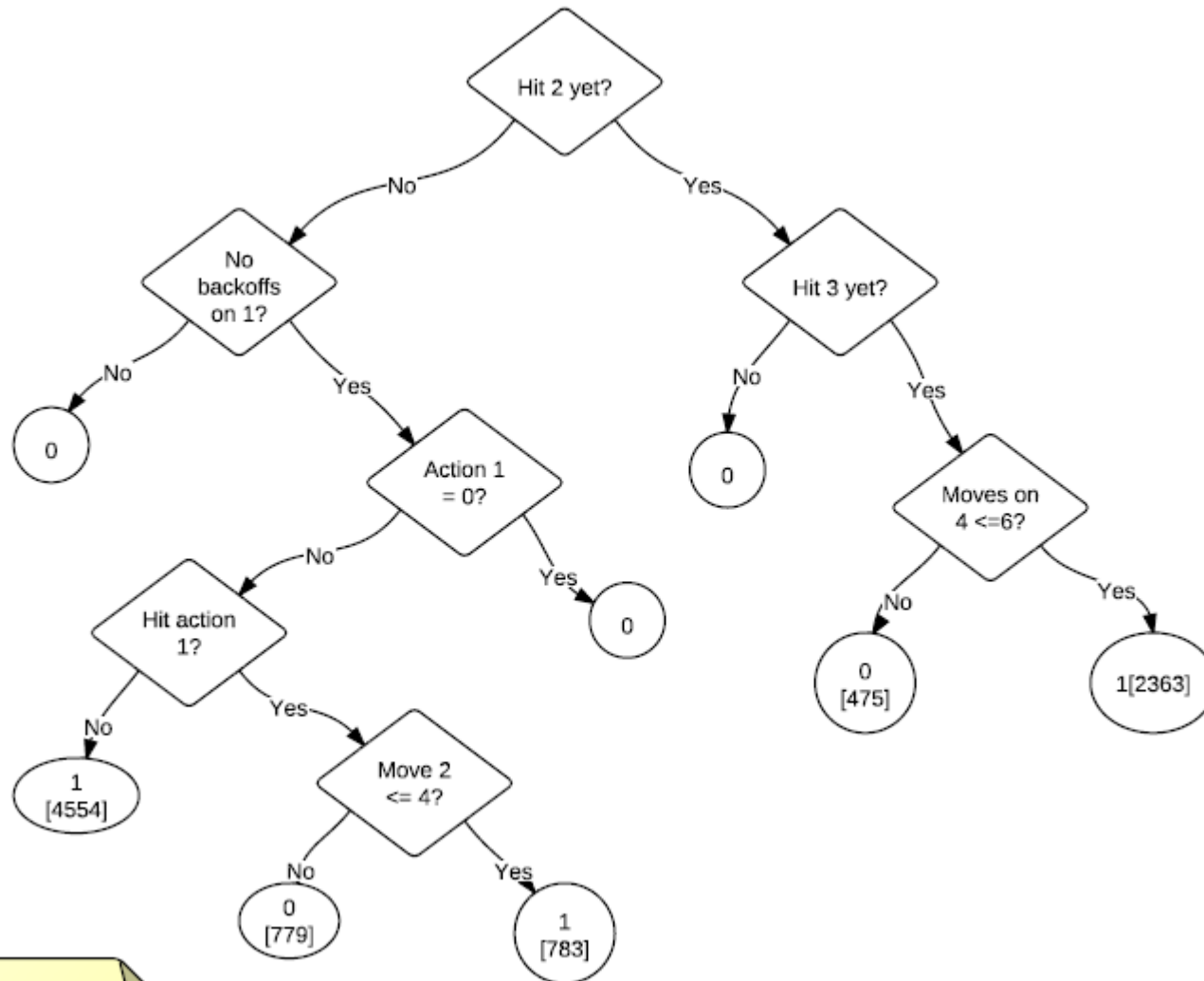
- (1) "Try using BOTH two-splitters" <point to one two-splitter>
- (2) "To make $\frac{1}{4}$, split the laser two times"
- (3) "None of the pieces split into four. How do you make $\frac{1}{4}$?"

Split Ordering:

- (1) "Try this piece first" <point to three-splitter>
- (2) "Split the laser in thirds first"
- (3) "Which splitter should you use first?"



RL Policy

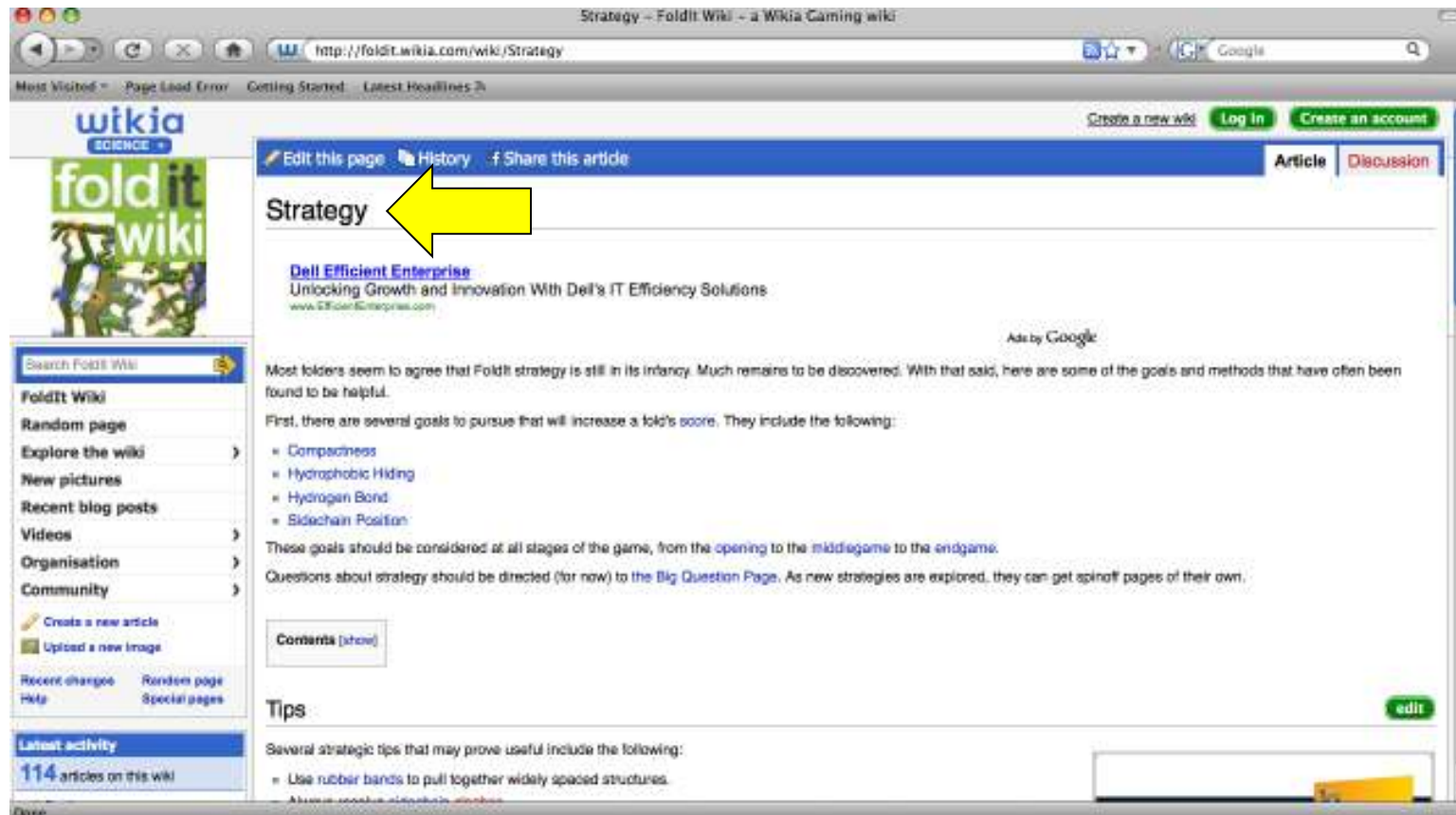


Social elements

- Team play
 - Direct realtime collaboration
 - Collective intelligence
 - Team competition
- Peer tutoring
- Intrinsic Motivation



Player Strategy Wiki



The screenshot shows a web browser window displaying the 'Strategy' page of the 'FoldIt Wiki'. The browser's address bar shows the URL 'http://foldit.wiki.com/wiki/Strategy'. The page features a blue header with navigation links: 'Edit this page', 'History', and 'Share this article'. A yellow arrow points to the 'Strategy' title. Below the title, there is a section for 'Dell Efficient Enterprise' with a subheading 'Unlocking Growth and Innovation With Dell's IT Efficiency Solutions' and a link to 'www.ETC.com/Enterprise'. An 'Ads by Google' section follows, containing text about FoldIt strategy and a list of goals: 'Compactness', 'Hydrophobic Hiding', 'Hydrogen Bond', and 'Sidechain Position'. A 'Contents (show)' button is visible. The 'Tips' section lists several strategic tips, including 'Use rubber bands to pull together widely spaced structures'. The left sidebar contains a search bar and various navigation links like 'FoldIt Wiki', 'Random page', 'Explore the wiki', 'New pictures', 'Recent blog posts', 'Videos', 'Organisation', 'Community', 'Create a new article', 'Upload a new image', 'Recent changes', 'Random page', 'Help', 'Special pages', and 'Latest activity' showing '114 articles on this wiki'. The bottom right corner of the page has an 'edit' button.

Strategy – FoldIt Wiki – a Wikia Gaming wiki

http://foldit.wiki.com/wiki/Strategy

Create a new wiki Log in Create an account

Edit this page History Share this article

Strategy

[Dell Efficient Enterprise](#)
Unlocking Growth and Innovation With Dell's IT Efficiency Solutions
www.ETC.com/Enterprise

Ads by Google

Most folders seem to agree that FoldIt strategy is still in its infancy. Much remains to be discovered. With that said, here are some of the goals and methods that have often been found to be helpful.

First, there are several goals to pursue that will increase a fold's score. They include the following:

- Compactness
- Hydrophobic Hiding
- Hydrogen Bond
- Sidechain Position

These goals should be considered at all stages of the game, from the [opening](#) to the [midgame](#) to the [endgame](#).

Questions about strategy should be directed (for now) to the [Big Question Page](#). As new strategies are explored, they can get spinoff pages of their own.

Contents (show)

Tips

Several strategic tips that may prove useful include the following:

- Use rubber bands to pull together widely spaced structures.

edit

Search FoldIt Wiki

FoldIt Wiki

Random page

Explore the wiki

New pictures

Recent blog posts

Videos

Organisation

Community

Create a new article

Upload a new image

Recent changes

Random page

Help

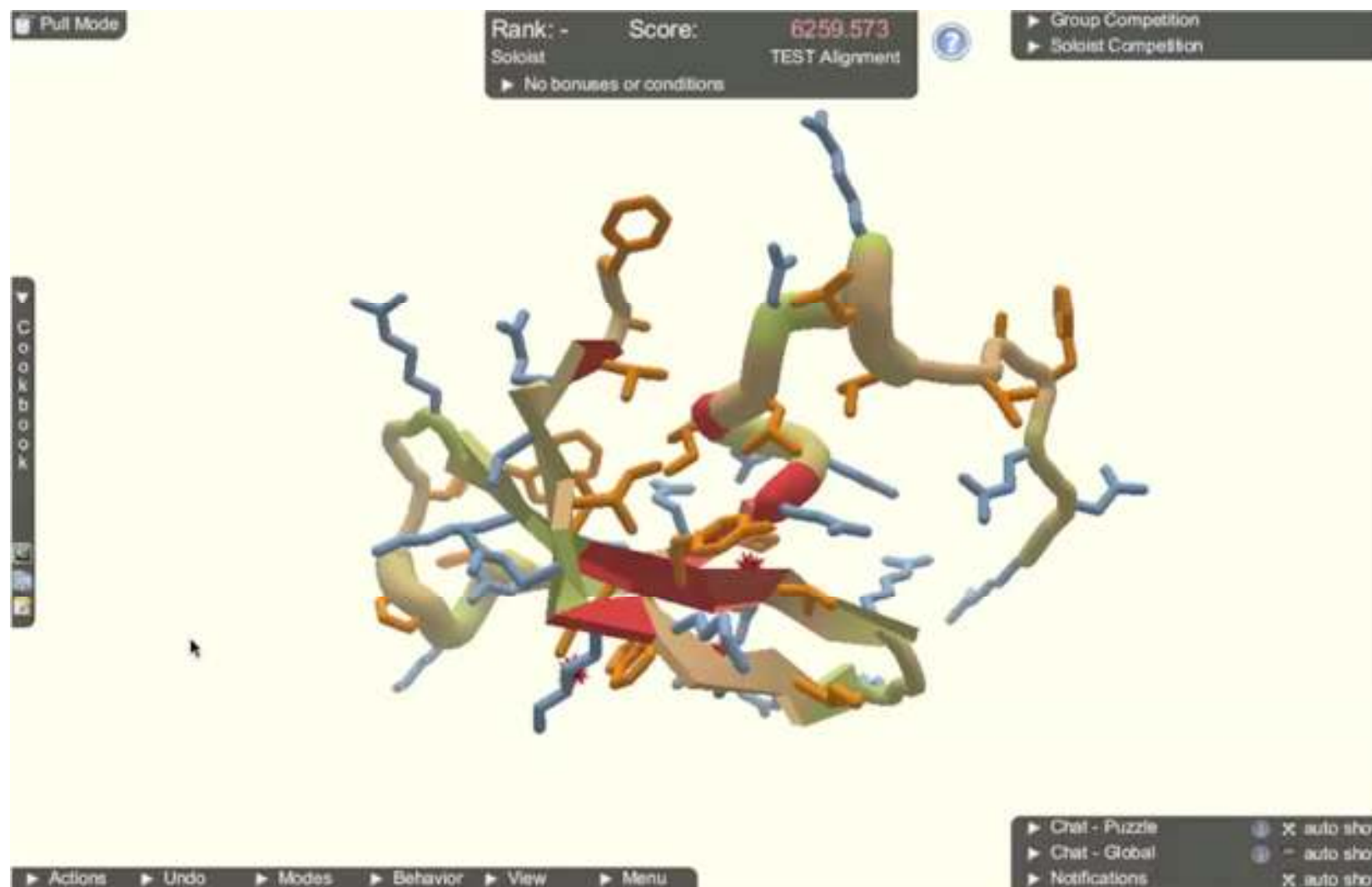
Special pages

Latest activity

114 articles on this wiki



Foldit Cookbook



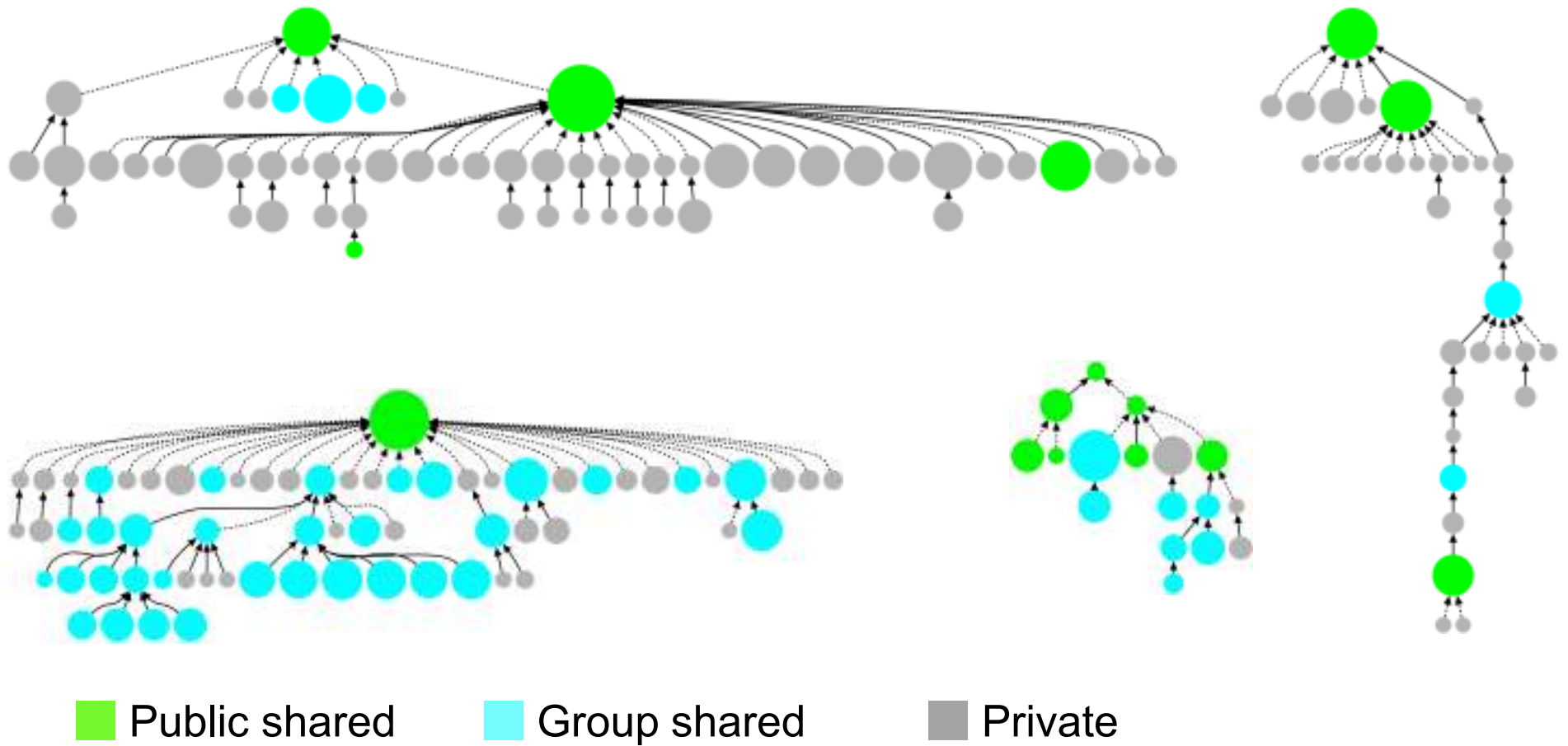
88%

of players run
others' recipes

32%

of players run only
others' recipes



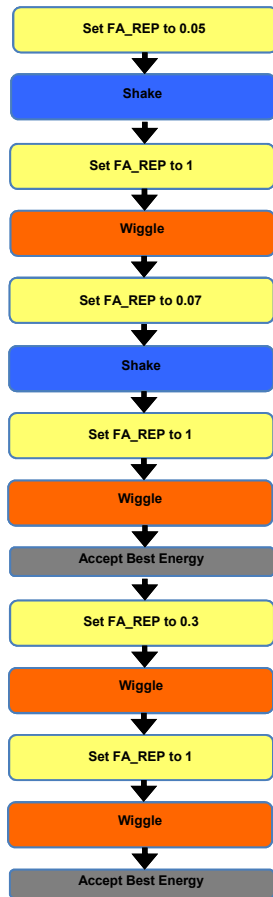


players are taking and modifying shared recipes



Algorithm Comparison

Player
Algorithm
(Blue Fuse v1.1)

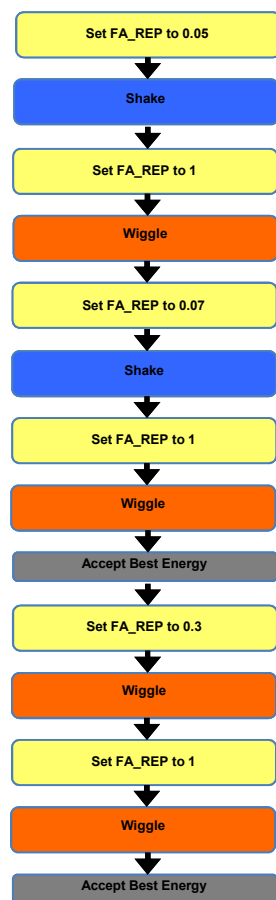


- Adjust repulsive force
- Discrete optimization
- Continuous optimization

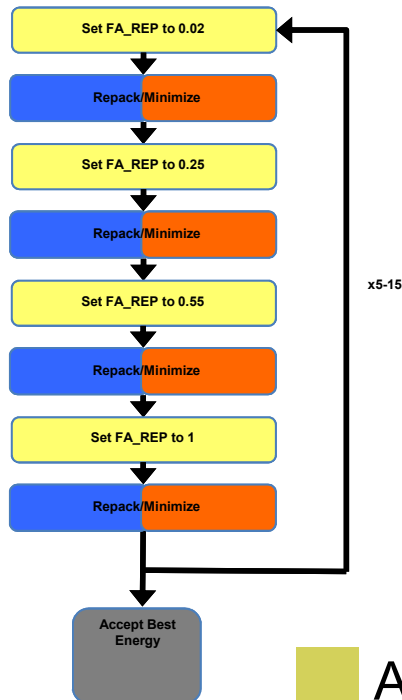


Algorithm Comparison

Player
Algorithm
(Blue Fuse v1.1)



Scientist
Algorithm
(Fast Relax)

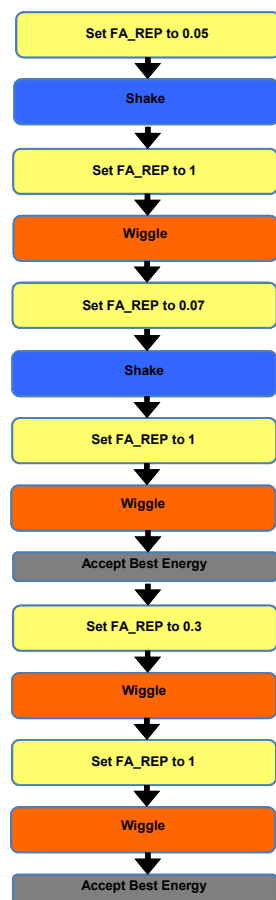


- Adjust repulsive force
- Discrete optimization
- Continuous optimization

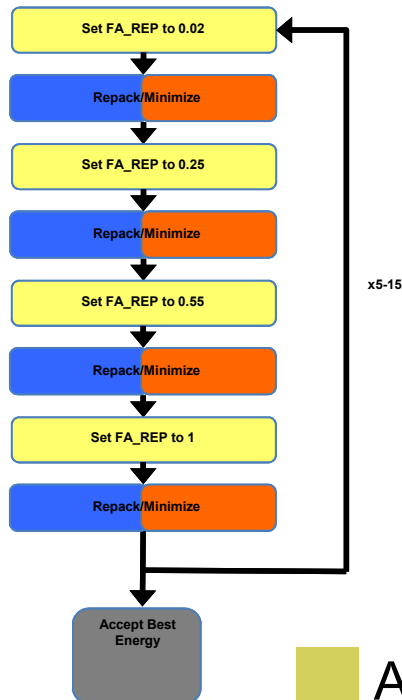


Algorithm Comparison

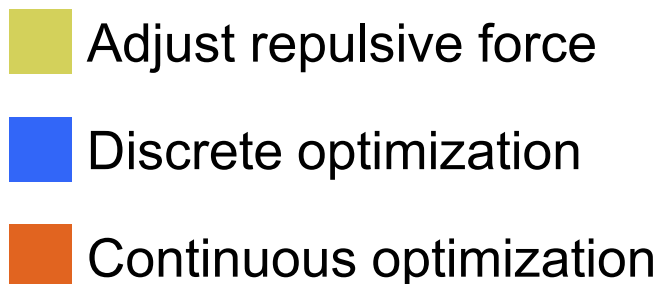
Player
Algorithm
(Blue Fuse v1.1)



Scientist
Algorithm
(Fast Relax)



- Independent discovery of scientists' algorithmic techniques



Self Identification





Level 6



Level 5



Level 7



Level 5

★ 24

Playing

Refraction





Iterative dual objective optimization

Program plan



Our reality

