Modeling Human Foraging

Brian D. Glass
Department of Psychology
University of Texas at Austin

Thanks to
W. Todd Maddox
Arthur B. Markman
Scott Lauritzen
Cognition & Perception Group

Foraging

What is foraging?

How organisms search their environment for resources (e.g., food, mates, information, etc.)

Why study foraging?

Foraging is a great way to address exploration/exploitation at the individual level.

Foraging

Exploitation:

Seek the “best” resource options

Exploration:

Willingness to try other, less appealing options

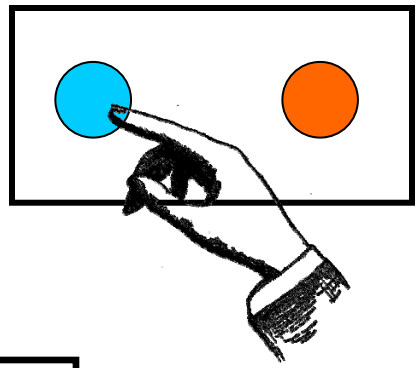
Overview

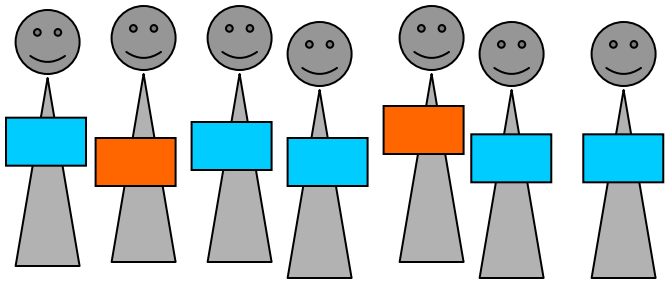
- What has been done with human foraging?
- Modification / upgrade of a foraging model
  - EPICURE
  - Generalized Exploration Model (GEM)
- Application of the model to the behavior of fatigued individuals

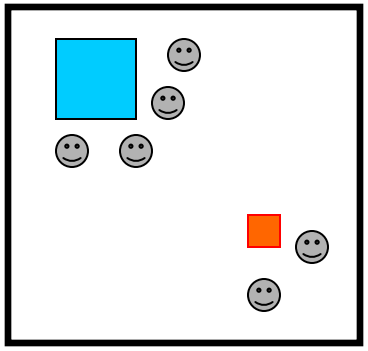
Foraging

What has been done with human foraging?

Group experiments that pit groups of
subjects against each other in the competition for resources.







What can you learn from group experiments like these?

You learn about group behavior, with little to say about behavior at the individual level

$$\frac{N_1}{N_2} = \frac{r_1}{r_2}$$

Matching laws can explain the group, but what is doing?

What can you learn from group experiments like these?

You learn about group behavior, with little to say about behavior at the individual level

$$\frac{N_1}{N_2} = b\left(\frac{r_1}{r_2}\right)^s$$

Matching laws can explain the group, but what is doing?

Foraging

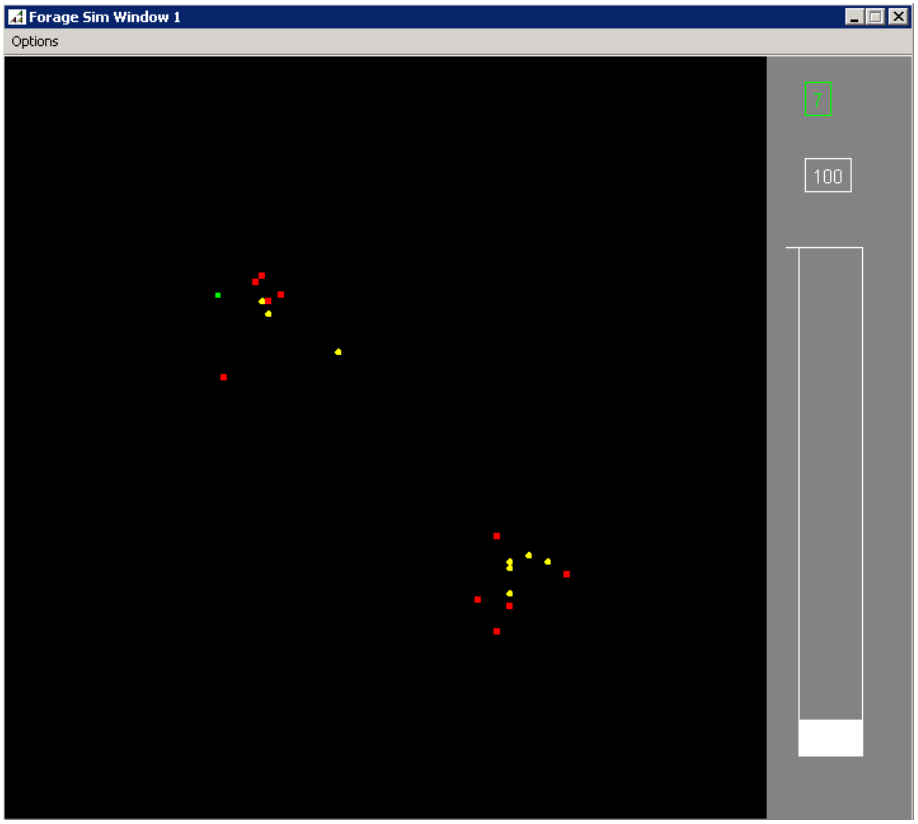
How do you figure out what individuals are doing?

One way is to control the behavior of the foragers, and figure out what kind of behavior leads to successful foraging performance.

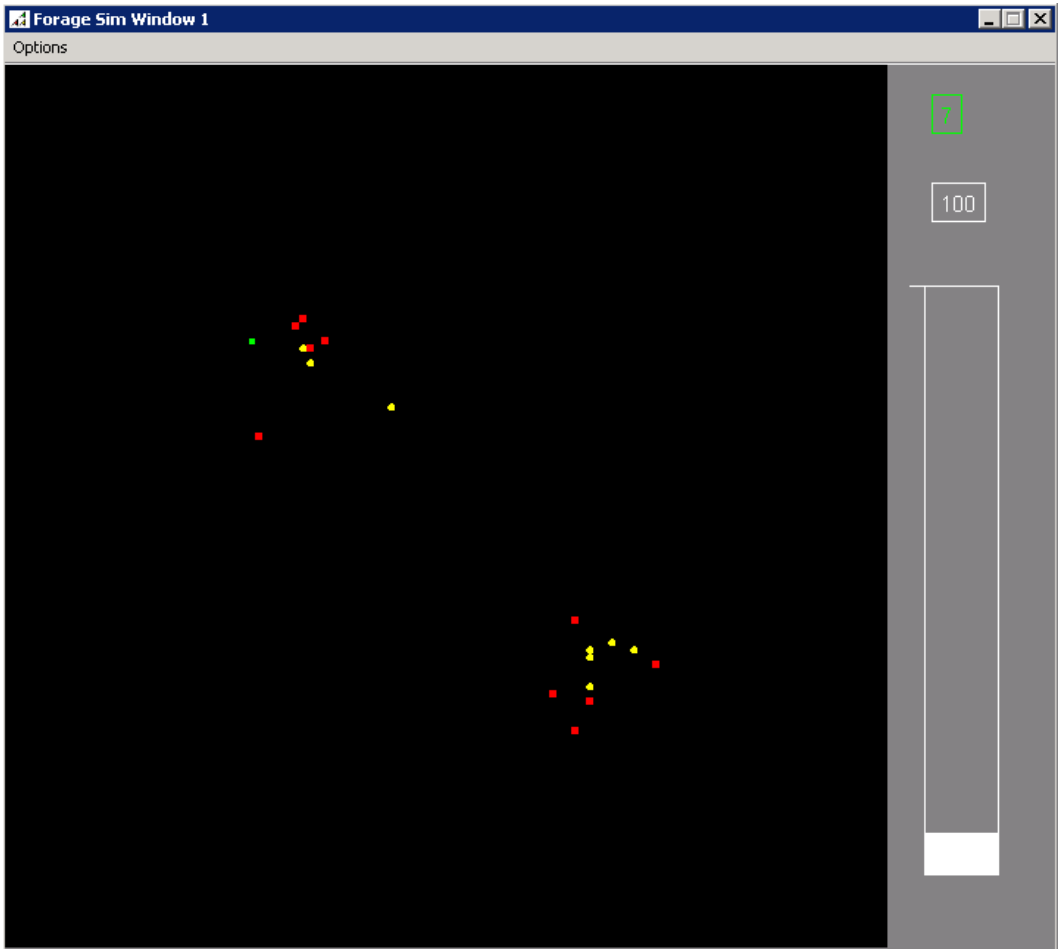
Luckily, there is already a task out that is fit for this job…

2D foraging

- Spatially explicit tasks (Goldstone & Roberts, 2005)
  - ✓ More strategies available to individuals
  - ✓ Many types of environments
  - ✓ Higher ecological validity



EPICURE model of human foraging



EPICURE:
(Roberts & Goldstone, 2005)

$$Value(i,j,t) = \left(P_1 * \frac{1}{fooddistance}\right) + (P_2 * fooddensity) \pm (P_3 * agentdensity) + (P_4 * rewards) - (P_5 * penalties) + \left(P_6 * \frac{1}{goaldistance}\right) \quad (1)$$

$$Probability\ of\ moving\ to\ space(i,j) = \frac{e^{Value(i,j,t)/K}}{\sum_x \sum_y e^{Value(i,j,t)/K}} \quad (2)$$

Exploration Parameter (K)

EPICURE model of human foraging

Probability of moving to space (i,j)

$$= \frac{e^{Value(i,j,t)/K}}{\sum_x \sum_y e^{Value(i,j,t)/K}}$$

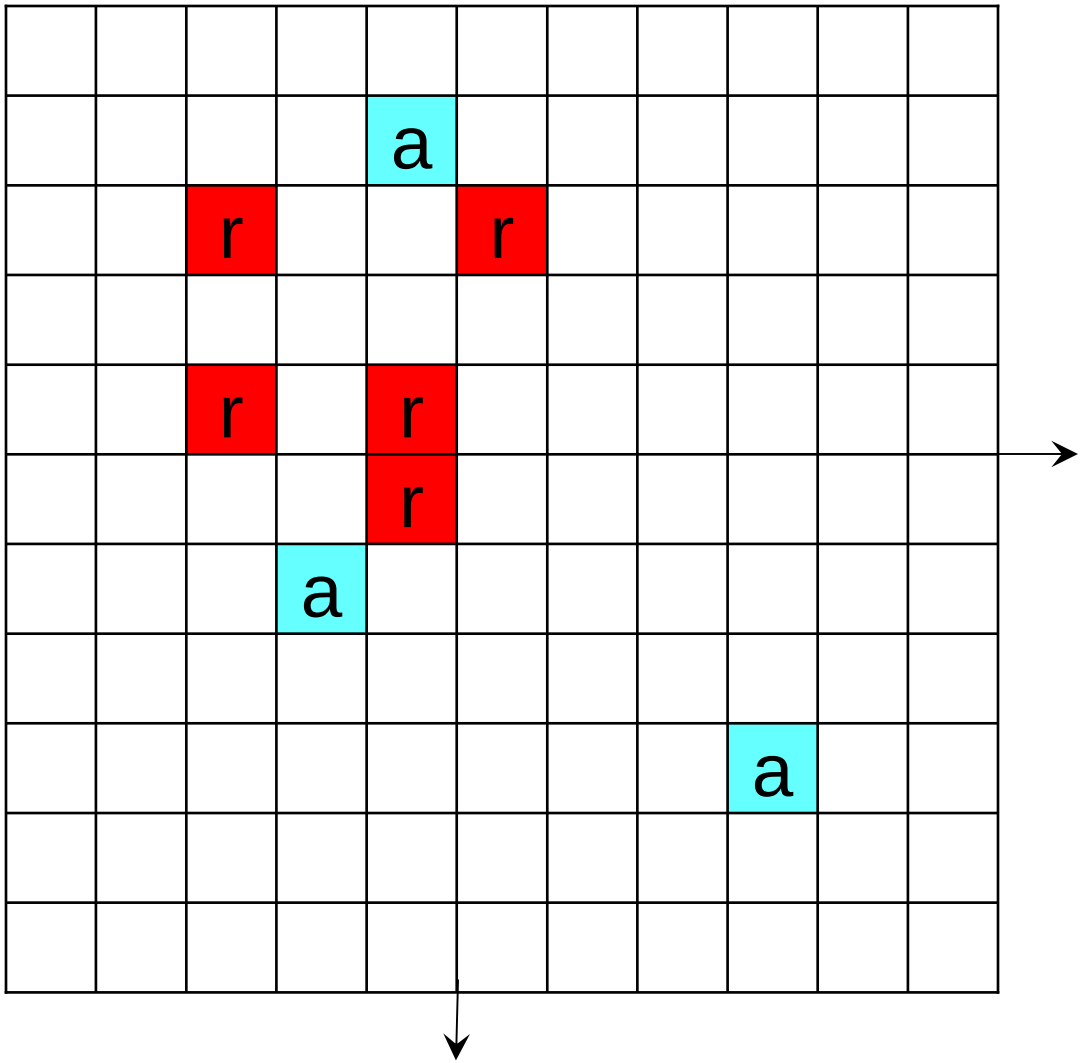
Exploration Parameter (*K*)

Lower → More likely to pick “best” option

Higher → More likely to try new options

The EPICURE environment

- 120 x 120 grid spaces
- Walls do not wrap
- No agent collision
- Agents have 8 DOF
- 1500 time steps
- 1 time step = 300msec
- Resources dropped into environment depending on relative reinforcement schedule of the pools



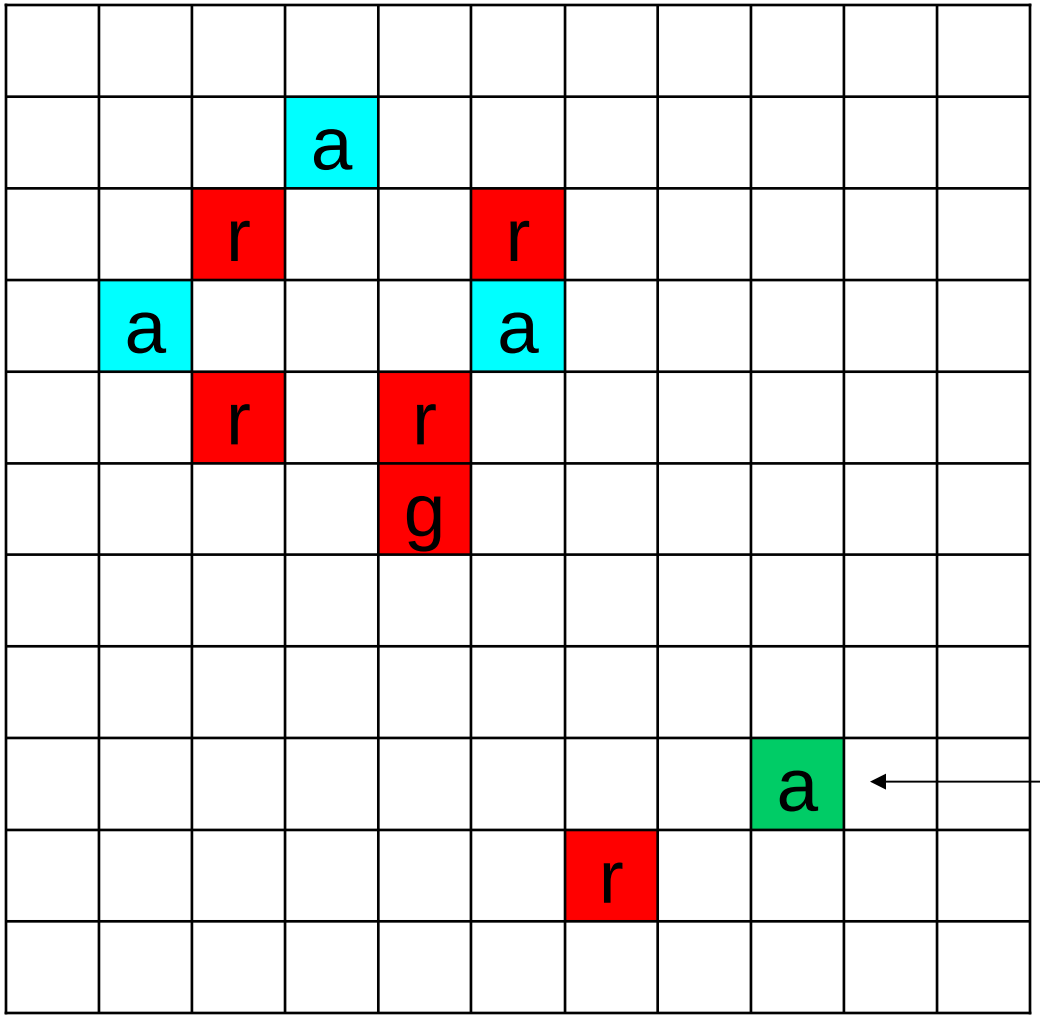
a - Agent

r - Resource

a - Agent

a - Competitor agent

r - Resource



EPICURE

Resource's value based on:

- Distance from agent
- Density of other resources
- Density of other agents
- Distance from goal location

a - Agent

a - Competitor agent

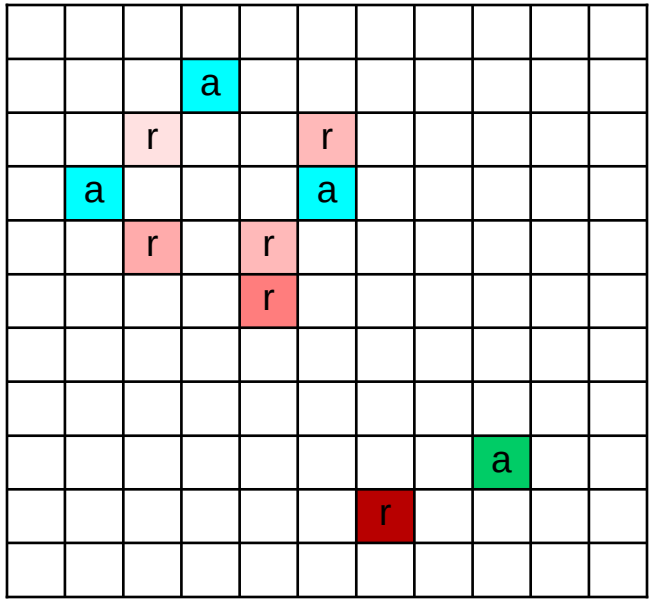
r - High likelihood resource

r - Low likelihood resource

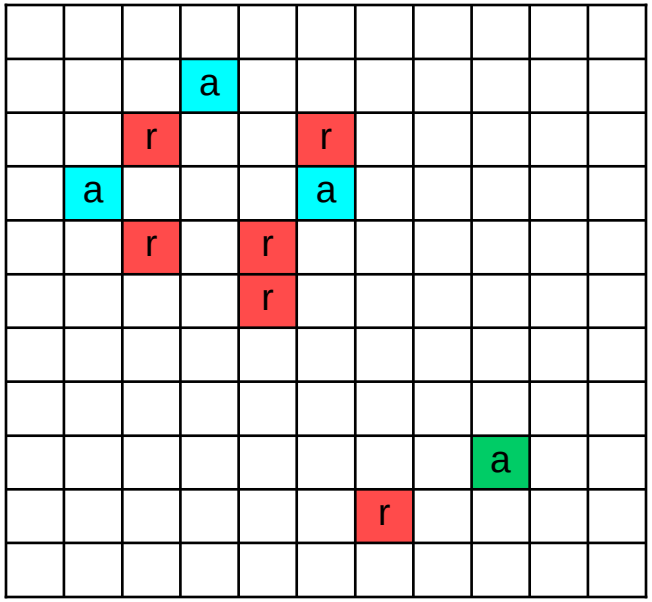
EPICURE

After each resource given a value, the agent probabilistically selects one to travel towards

Exploitative Agent



Exploratory Agent



From EPICURE to GEM

- EPICURE is just one of a whole class of models, some of which are more psychologically valid

- To address psychological issues, the Generalized Exploration Model (GEM) includes more features

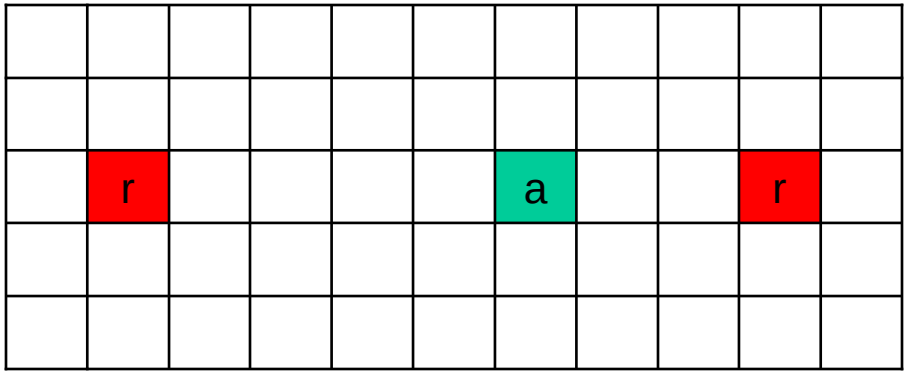
- EPICURE remains a sub-model of GEM

EPICURE issues

- Local agent behavior is unrealistic
- Agents oscillate between equally attractive resource locations because they pick a new goal on each time step
- Agents with higher exploration parameter do not switch between resource locations more often than agents with low exploration parameter

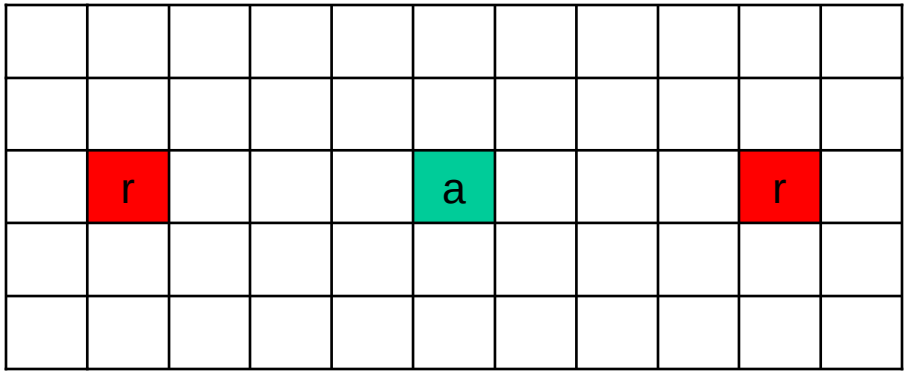
Addressing EPICURE issues

- Agents get “stuck” between resource options



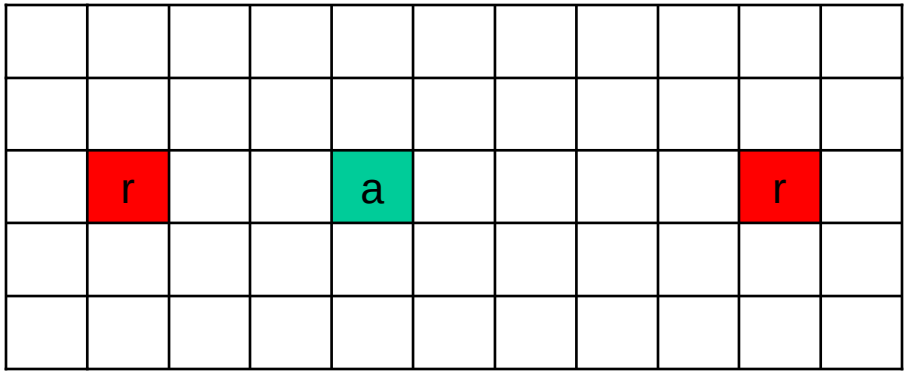
Addressing EPICURE issues

- Agents get “stuck” between resource options



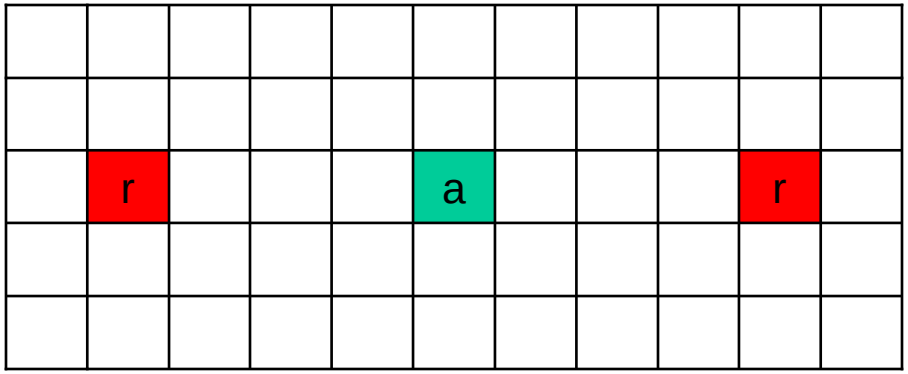
Addressing EPICURE issues

- Agents get “stuck” between resource options



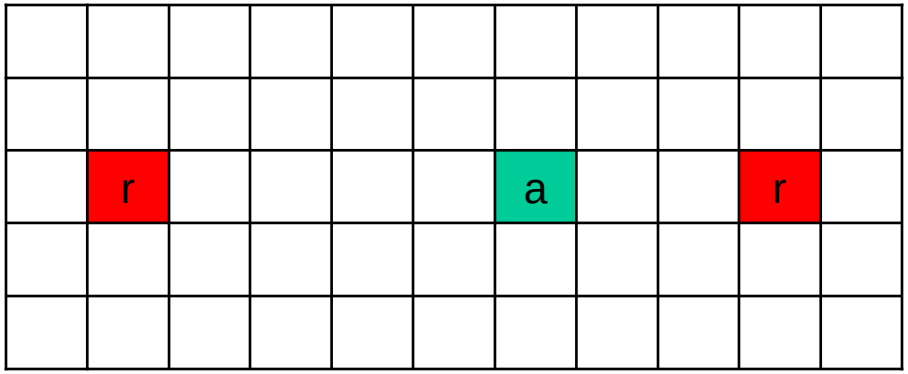
Addressing EPICURE issues

- Agents get “stuck” between resource options



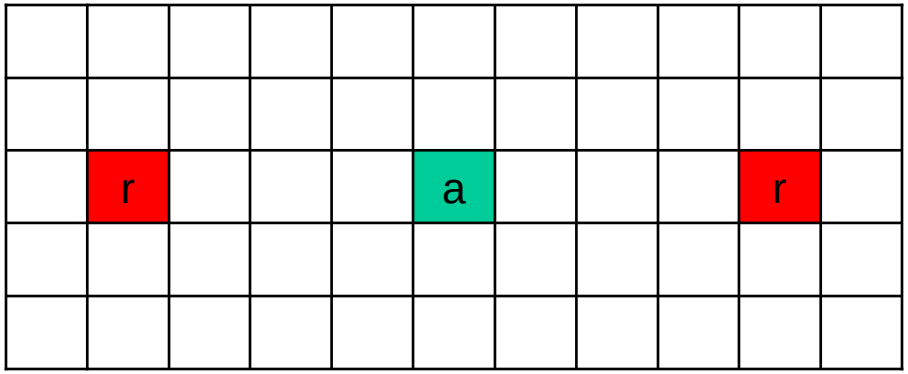
Addressing EPICURE issues

- Agents get “stuck” between resource options



Addressing EPICURE issues

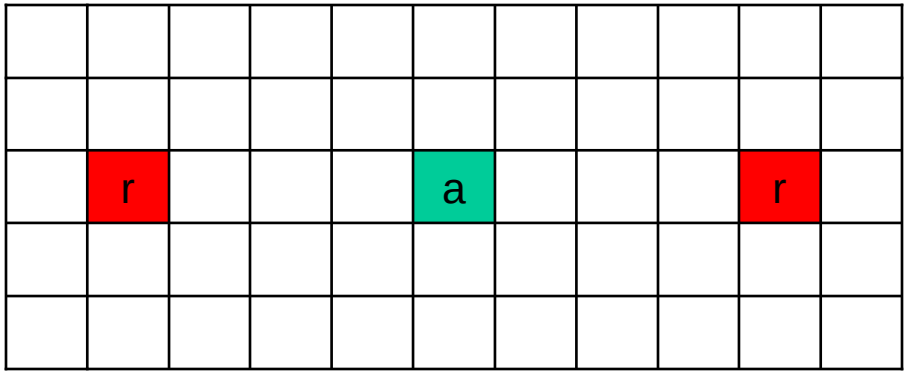
- Agents get “stuck” between resource options



Solution:

Agents pick a goal location and continue moving towards it

Addressing EPICURE issues



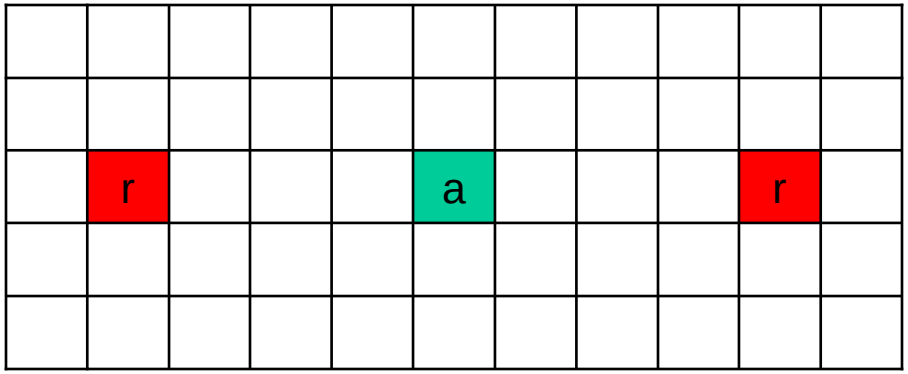
Solution:

Agents pick a goal location and continue moving towards it

Addressing EPICURE issues

Solution:

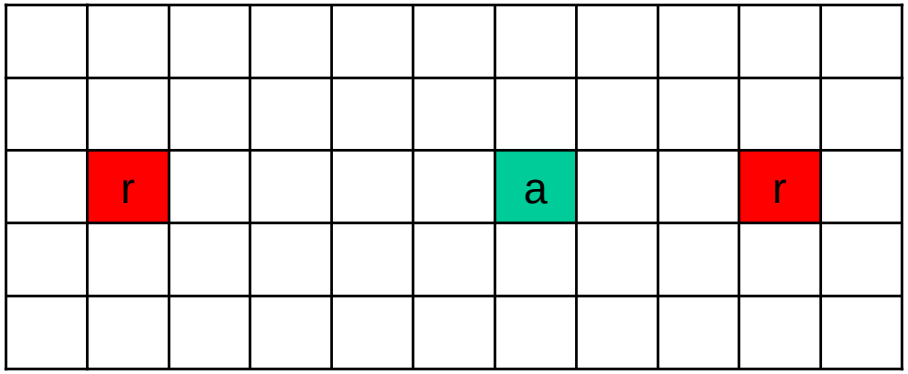
Agents pick a goal location and continue moving towards it



Addressing EPICURE issues

Solution:

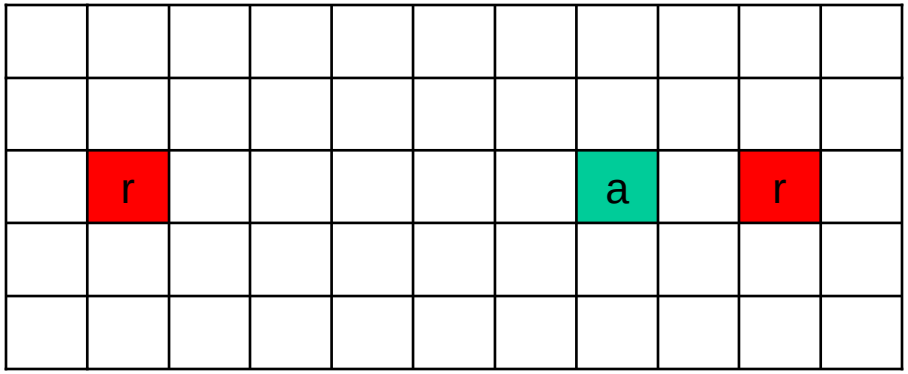
Agents pick a goal location and continue moving towards it



Addressing EPICURE issues

Solution:

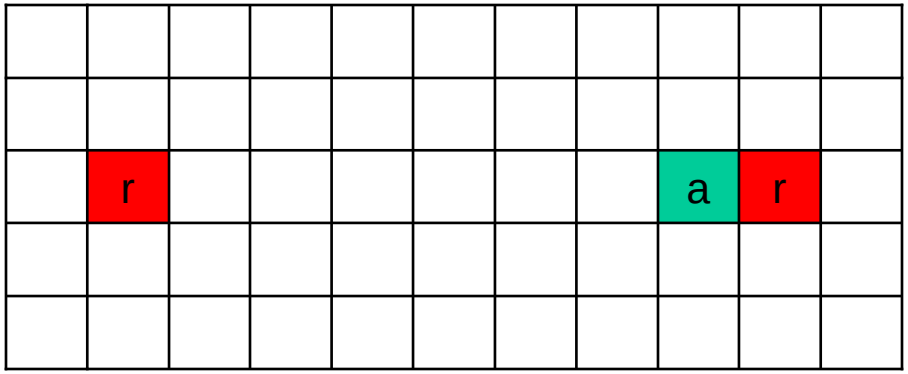
Agents pick a goal location and continue moving towards it



Addressing EPICURE issues

Solution:

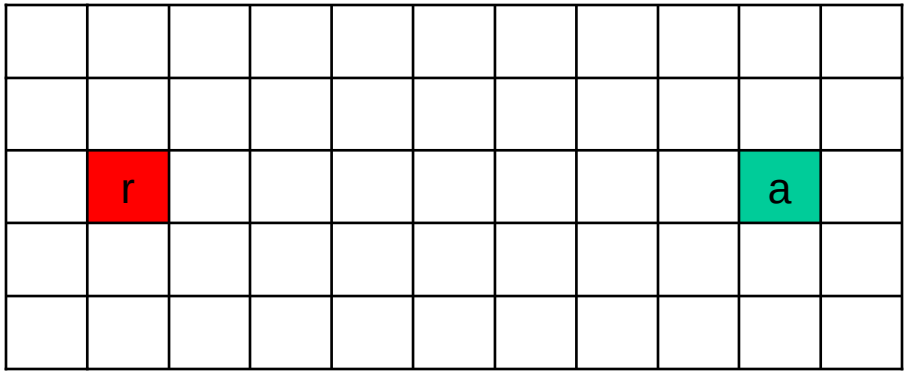
Agents pick a goal location and continue moving towards it



Addressing EPICURE issues

Solution:

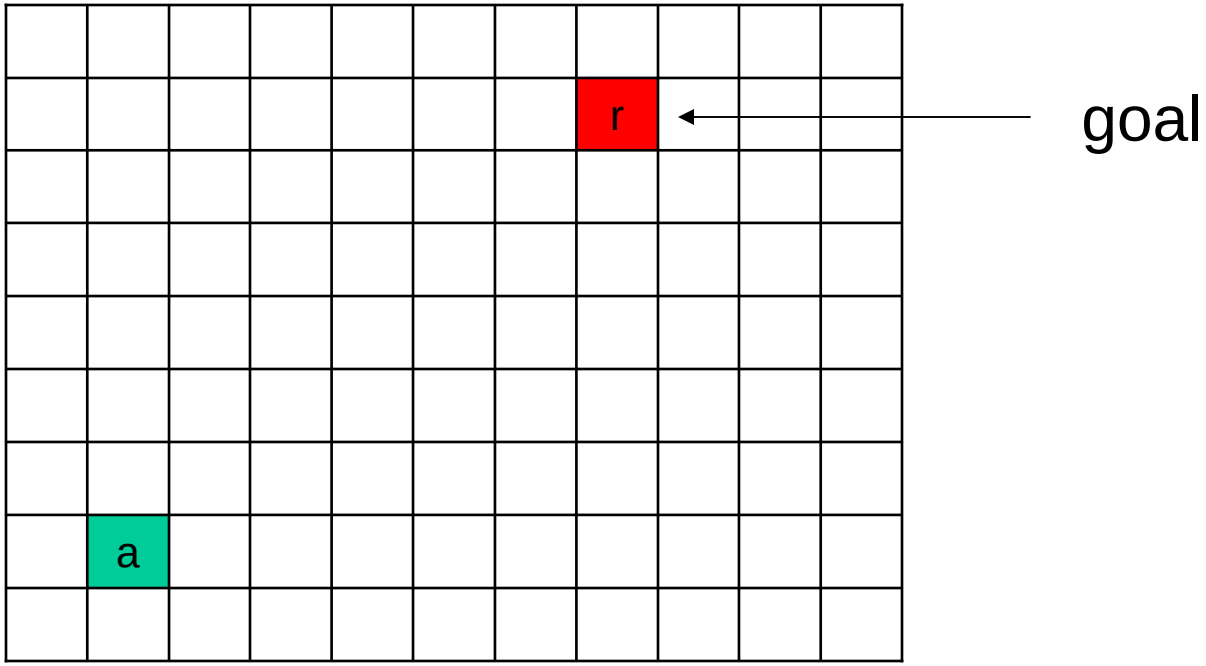
Agents pick a goal location and continue moving towards it



Addressing EPICURE issues

New problem:

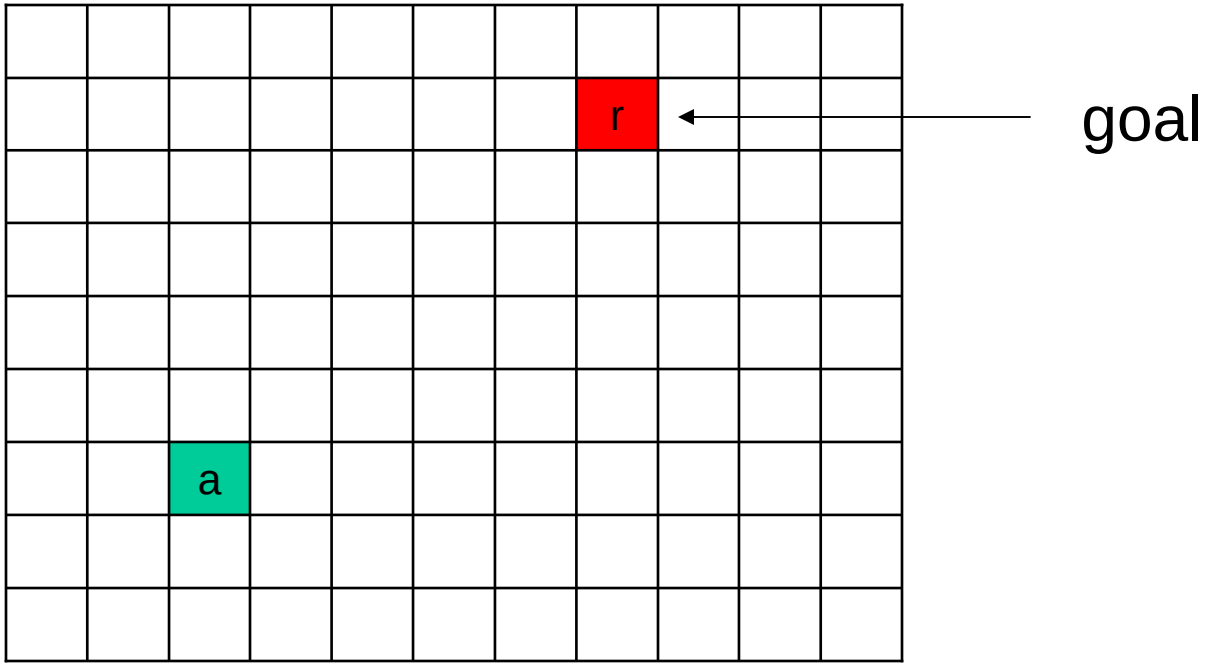
Agents will pass up nearby opportunities that arise…



Addressing EPICURE issues

New problem:

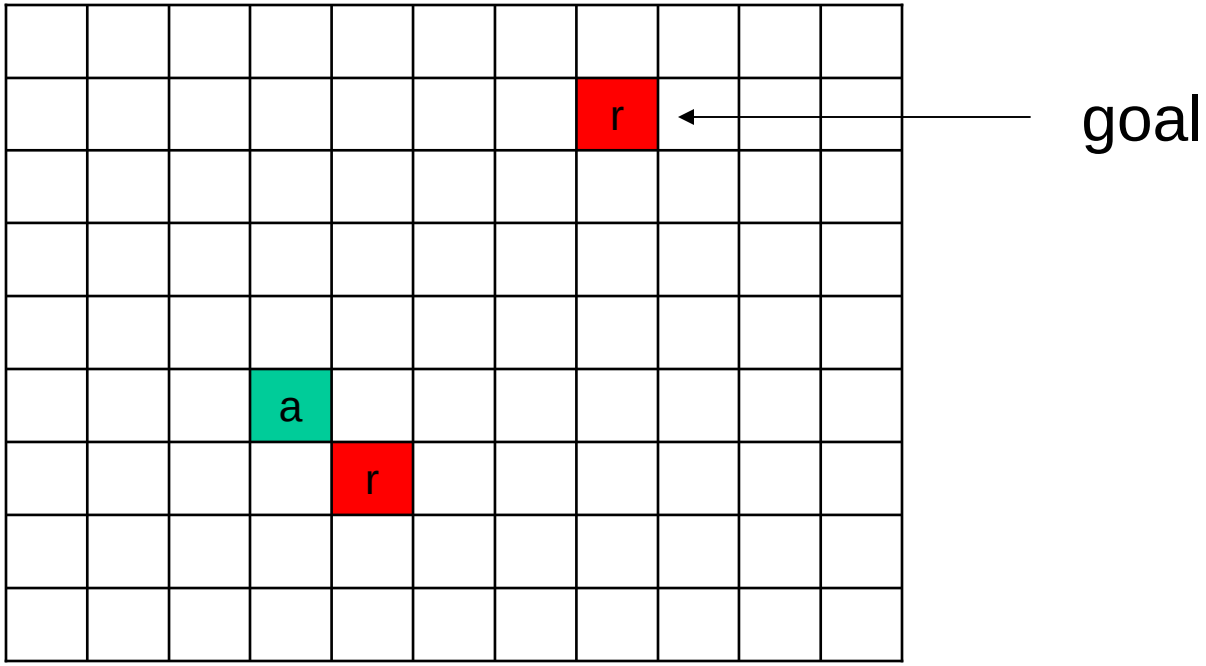
Agents will pass up nearby opportunities that arise…



Addressing EPICURE issues

New problem:

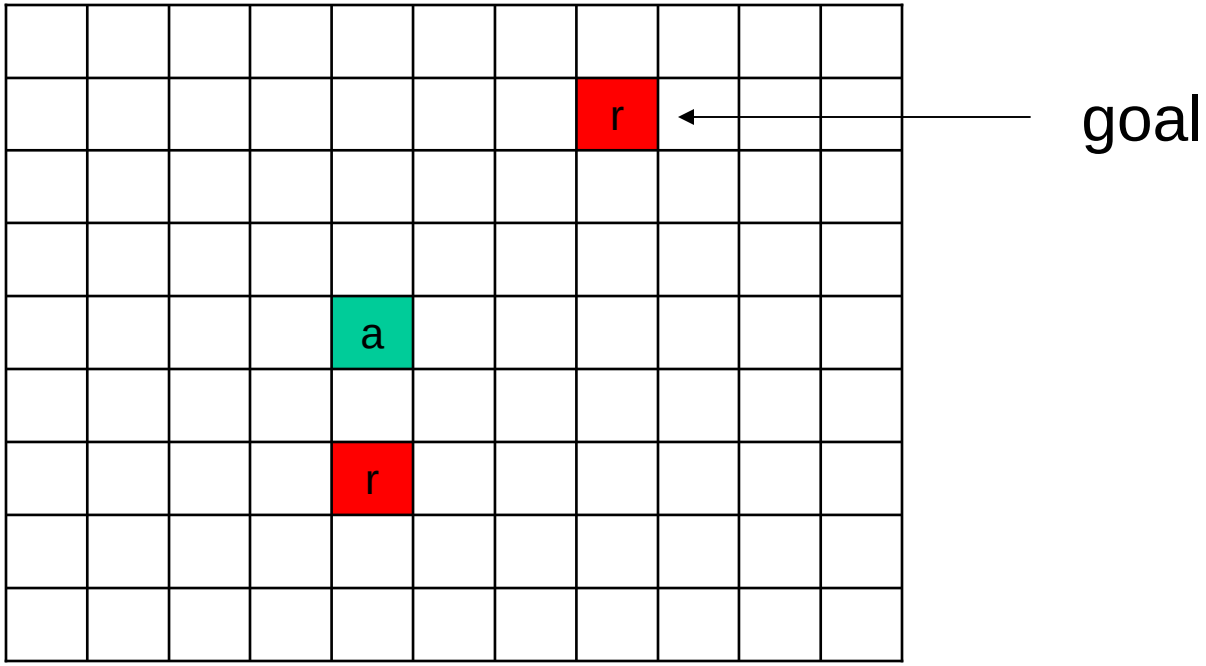
Agents will pass up nearby opportunities that arise…



Addressing EPICURE issues

New problem:

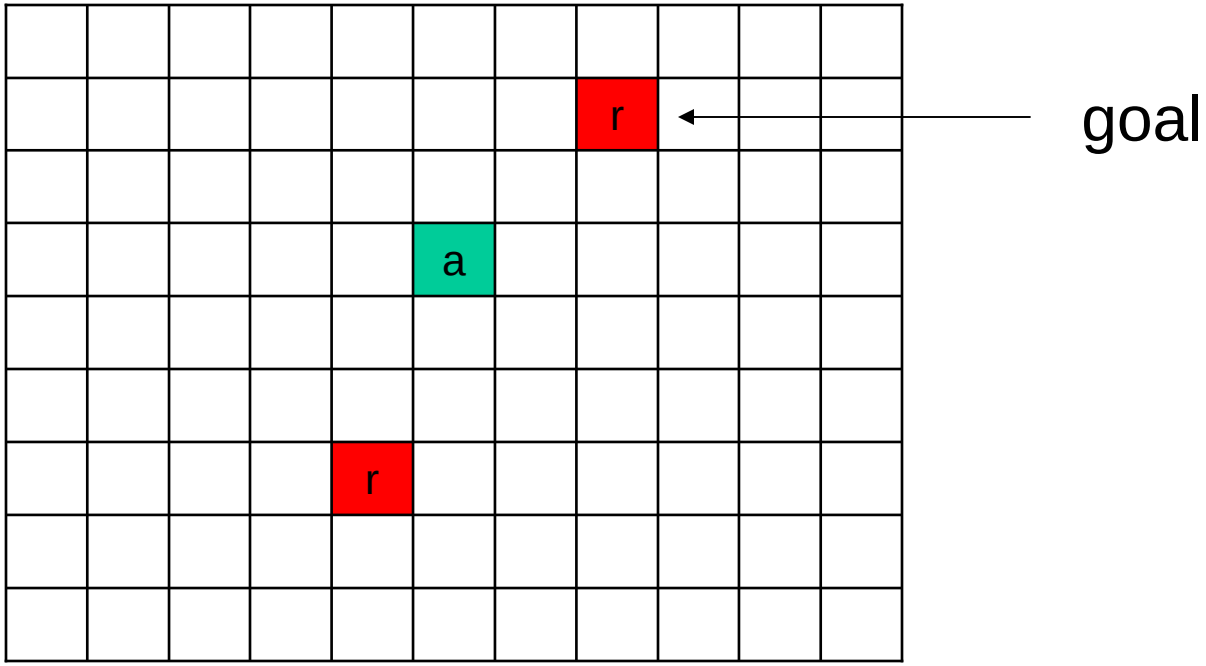
Agents will pass up nearby opportunities that arise…



Addressing EPICURE issues

New problem:

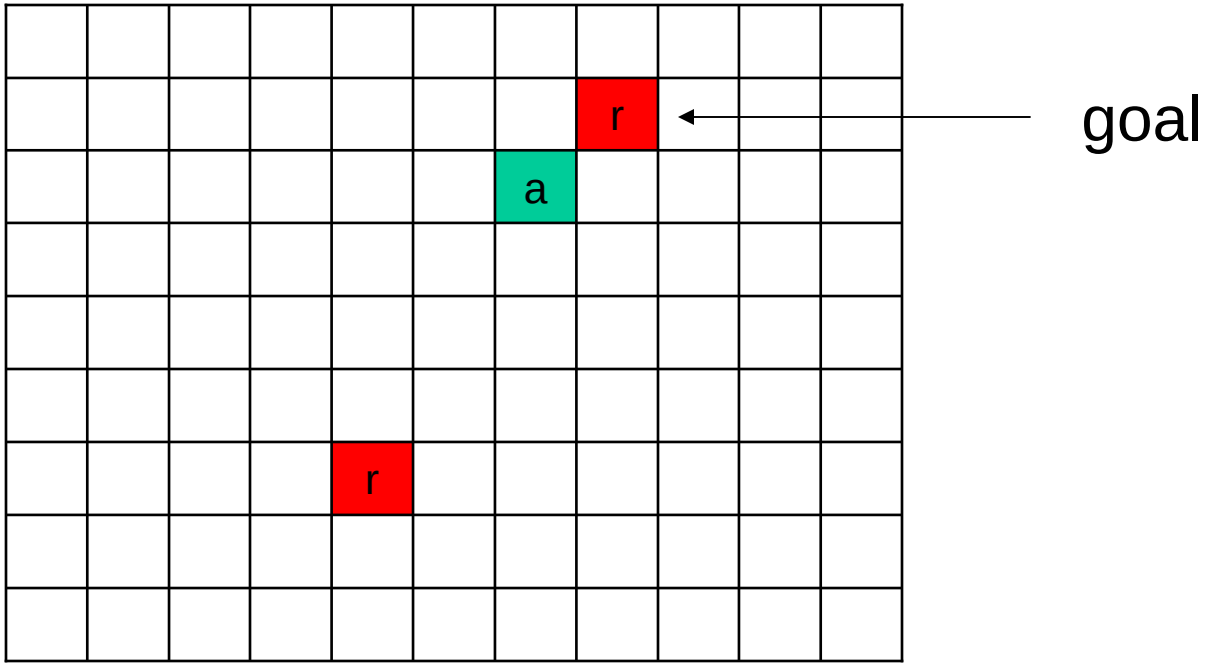
Agents will pass up nearby opportunities that arise…



Addressing EPICURE issues

New problem:

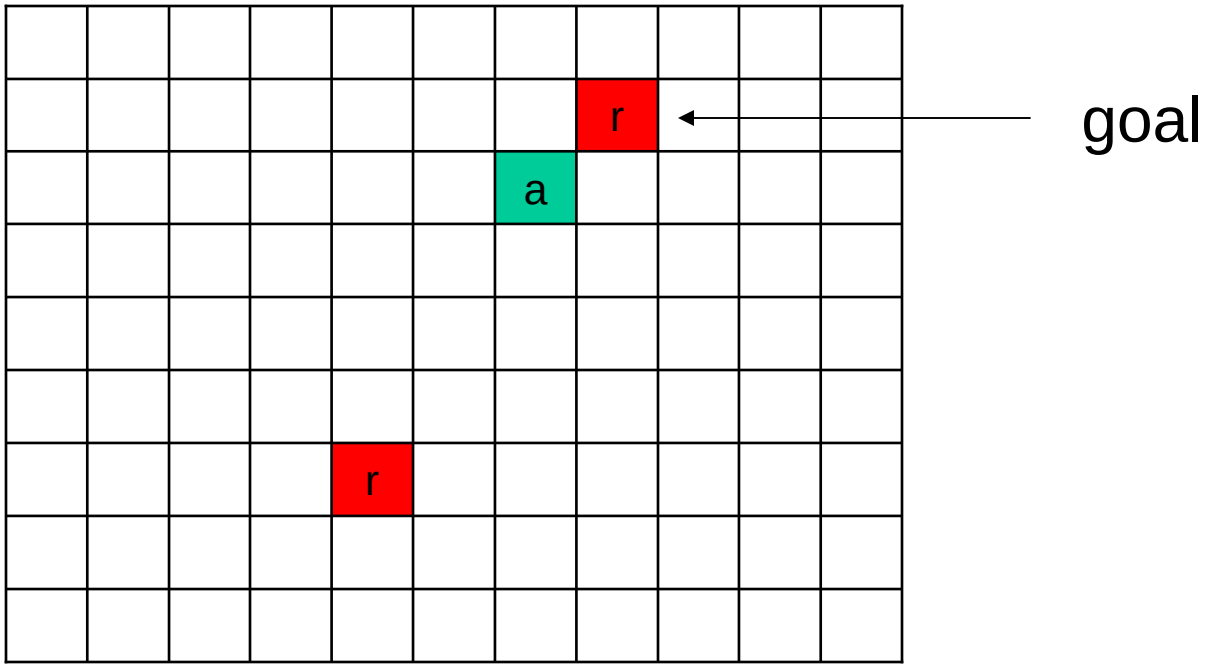
Agents will pass up nearby opportunities that arise…



Addressing EPICURE issues

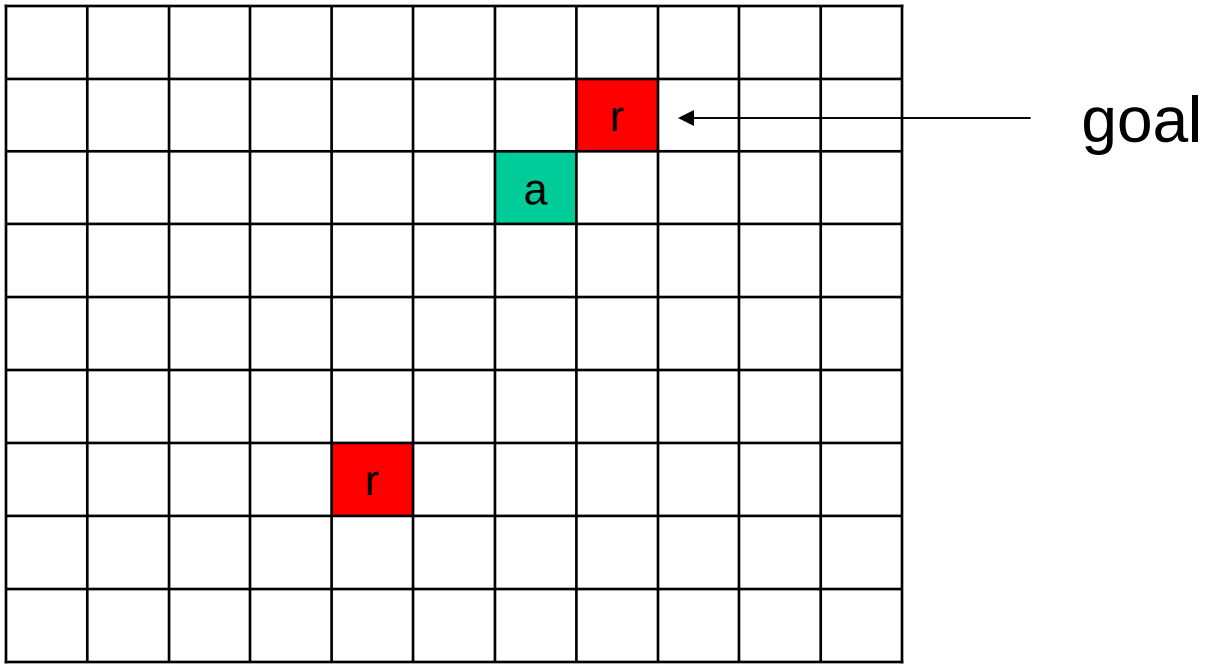
New problem:

Agents will pass up nearby opportunities that arise…



Solution: Use memory stack of goal locations

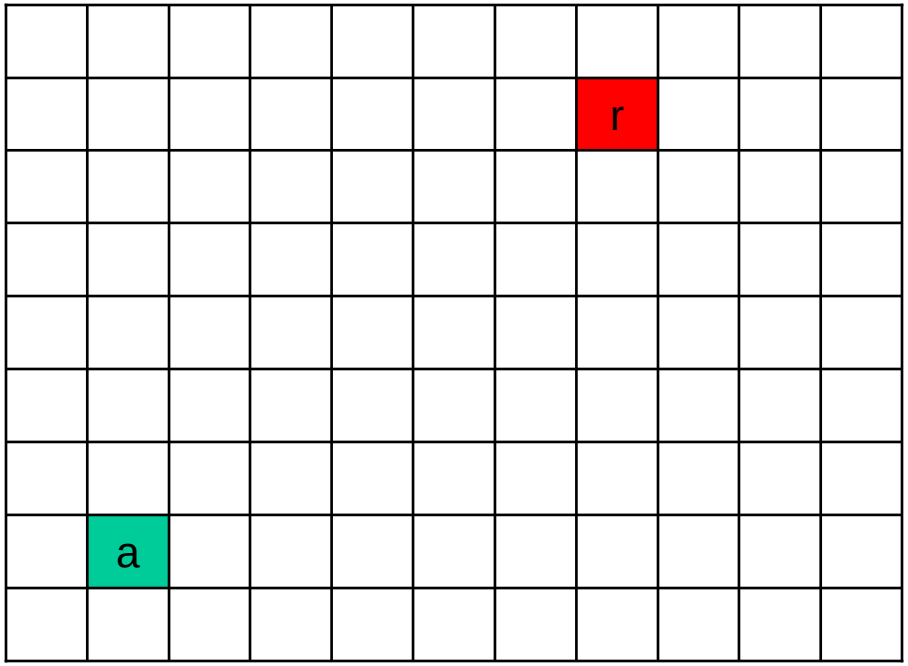
Addressing EPICURE issues



Solution: Use memory stack of goal locations

Addressing EPICURE issues

Solution: Use memory stack of goal locations

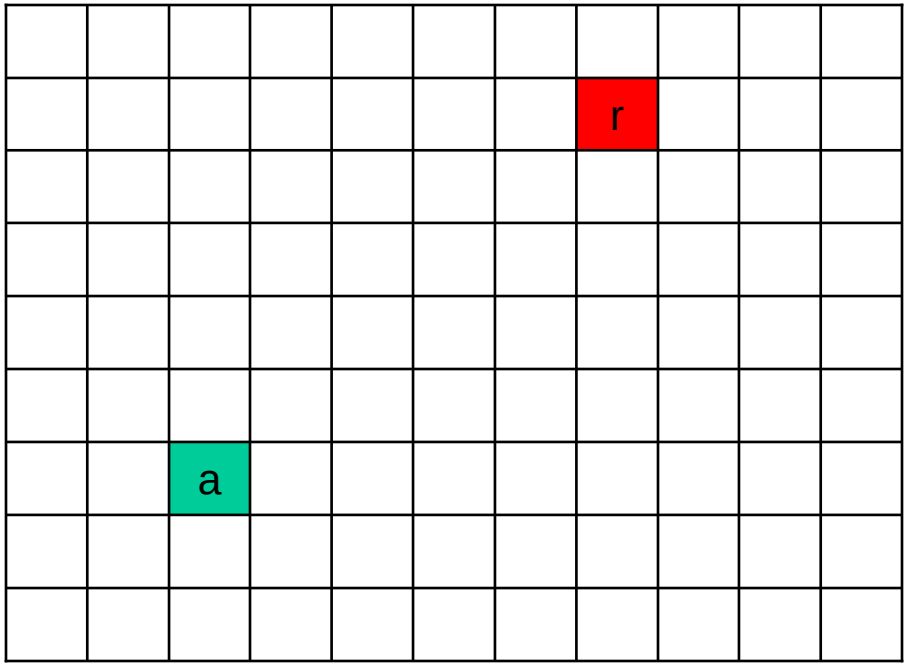


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations

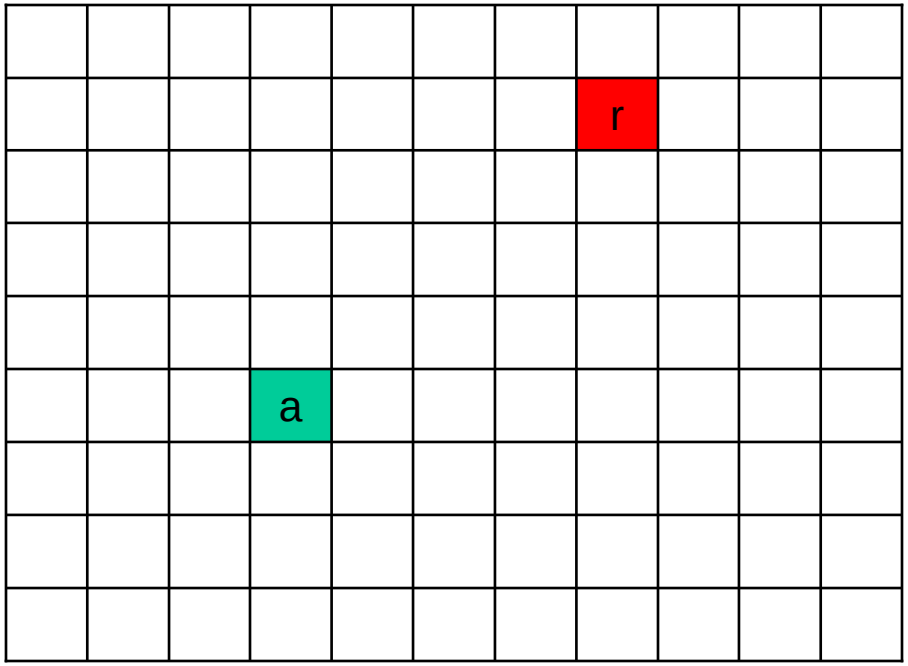


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations

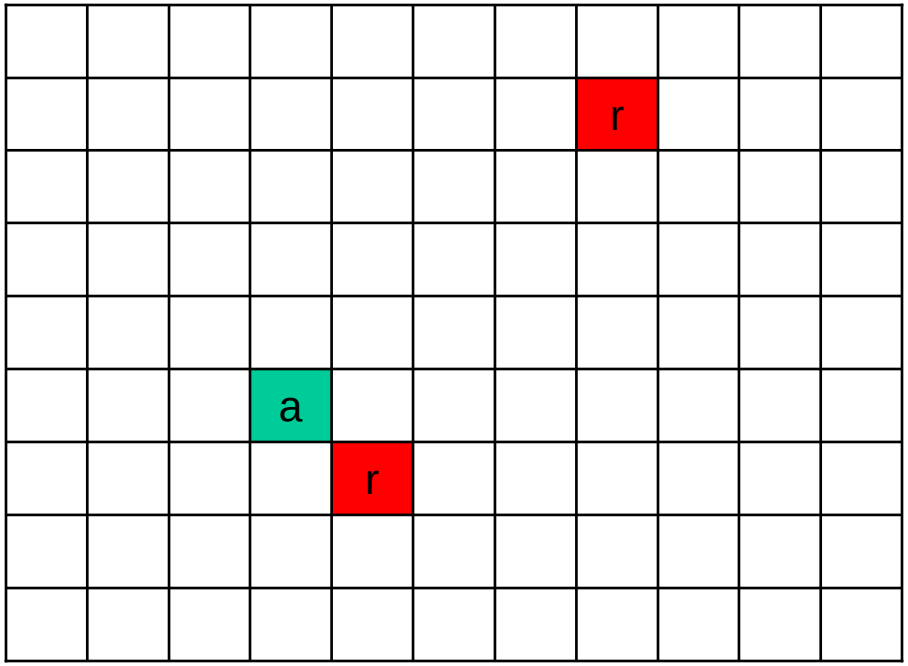


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations

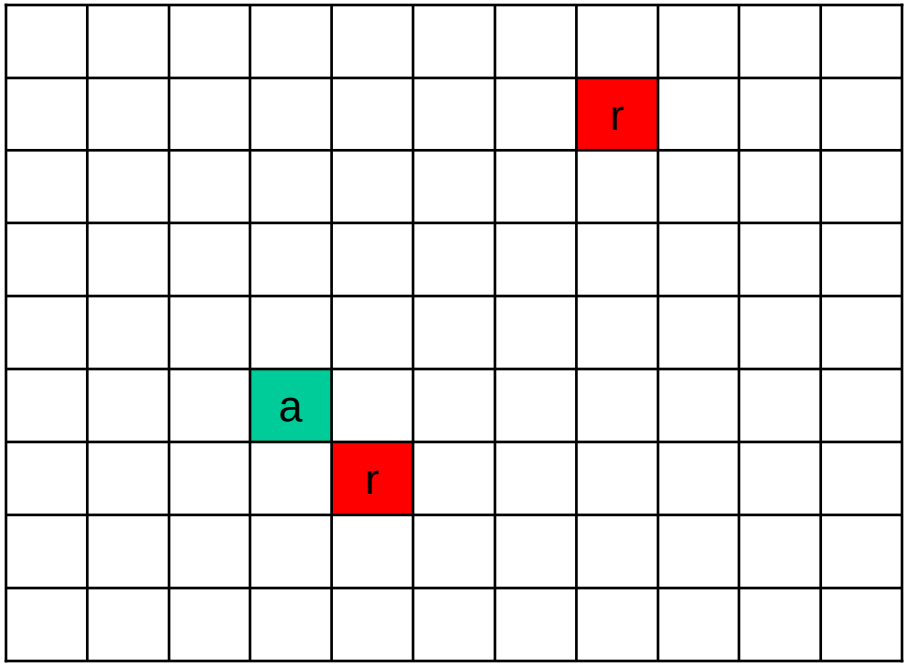


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations

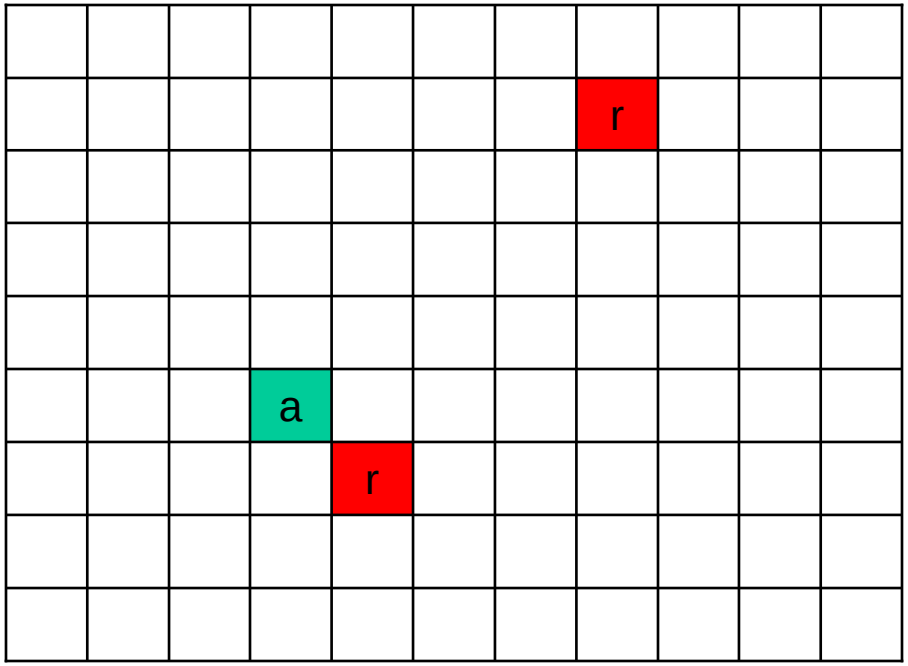


Memory stack:

1	(8,2)
2	(5,7)

Addressing EPICURE issues

Solution: Use memory stack of goal locations

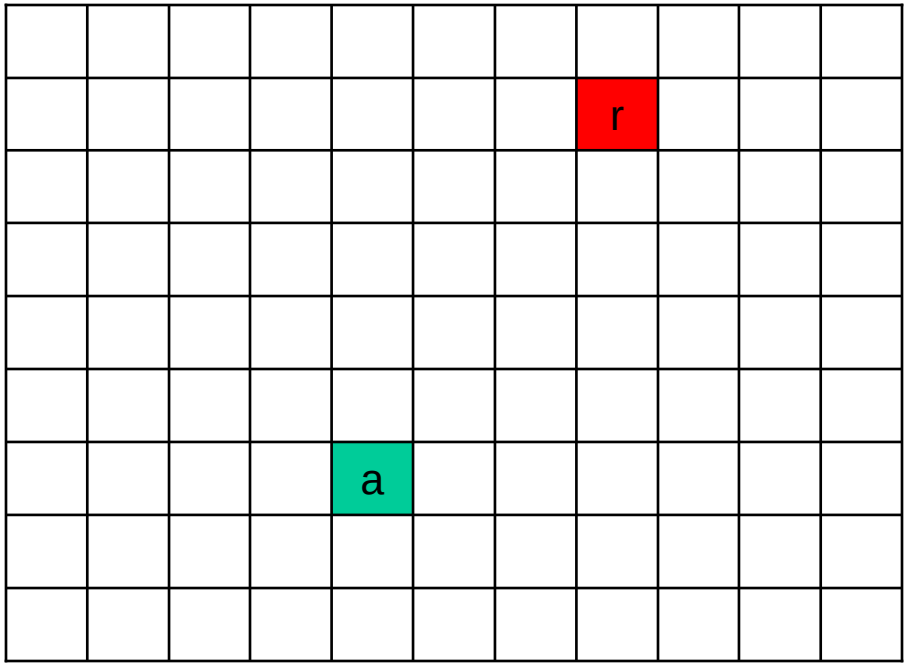


Memory stack:

1	(5,7)
2	(8,2)

Addressing EPICURE issues

Solution: Use memory stack of goal locations

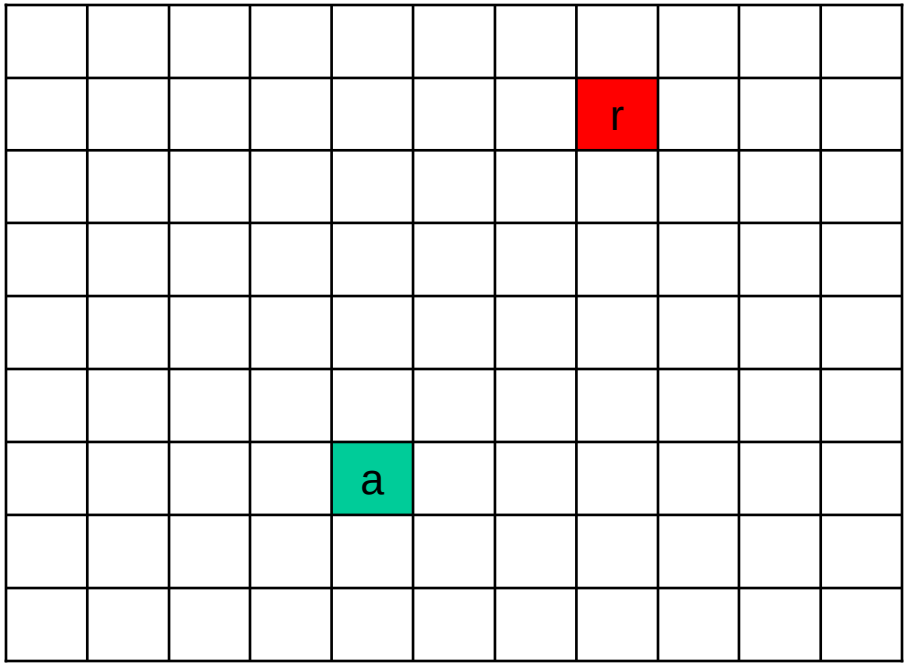


Memory stack:

1	(5,7)
2	(8,2)

Addressing EPICURE issues

Solution: Use memory stack of goal locations

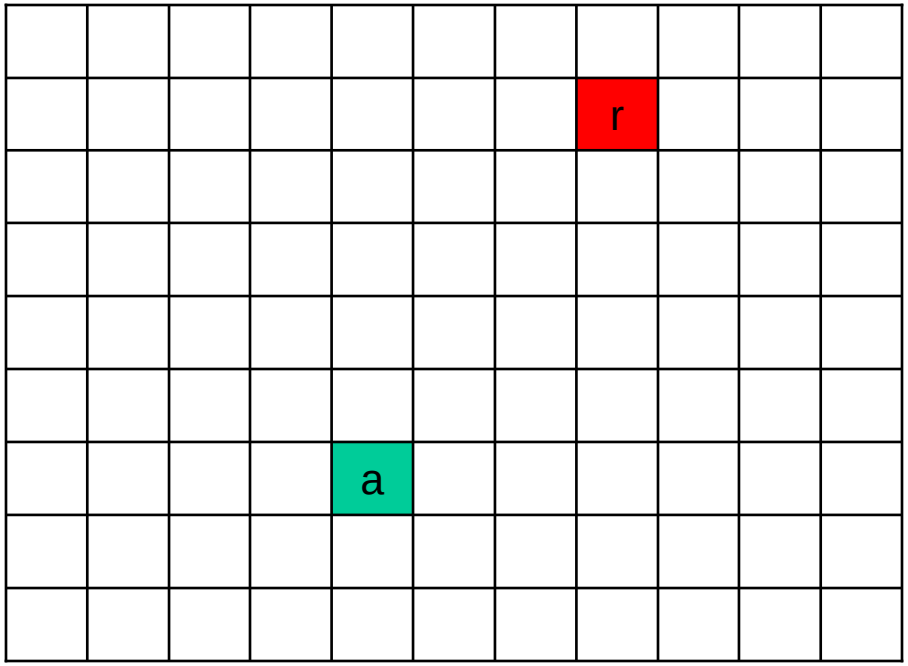


Memory stack:

1	empty
2	(8,2)

Addressing EPICURE issues

Solution: Use memory stack of goal locations

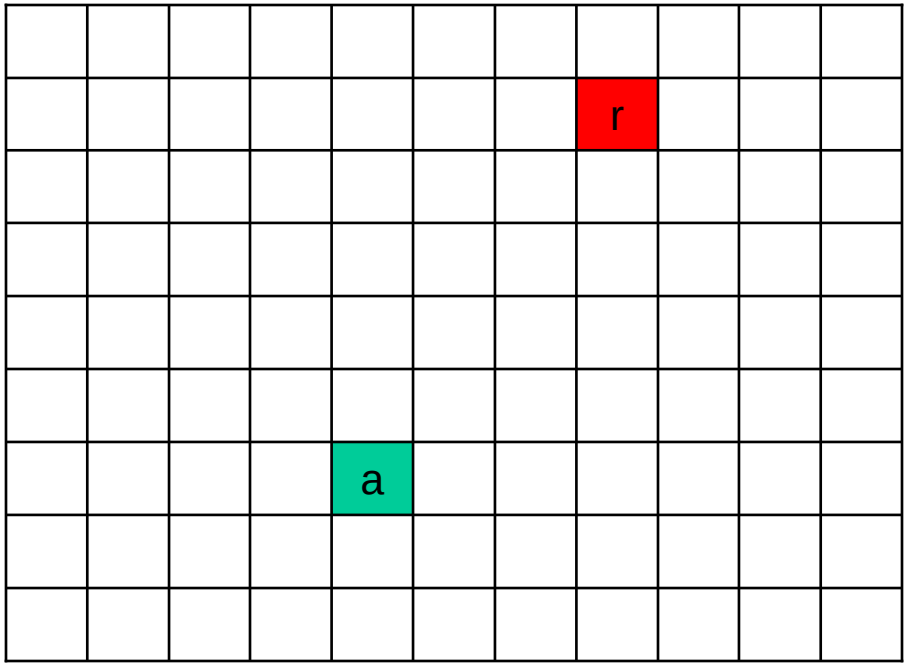


Memory stack:

1	empty
2	(8,2)

Addressing EPICURE issues

Solution: Use memory stack of goal locations

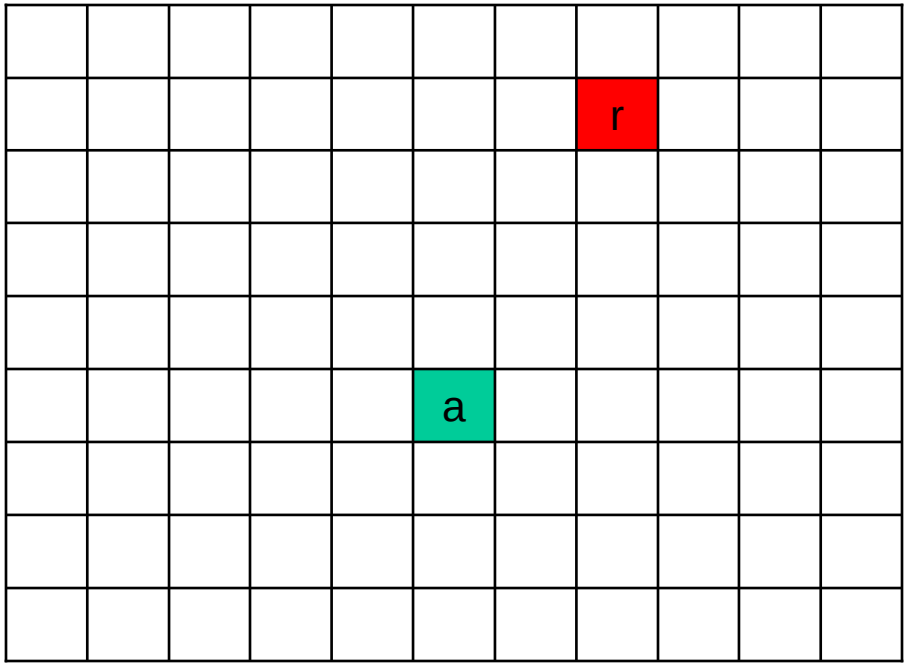


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations

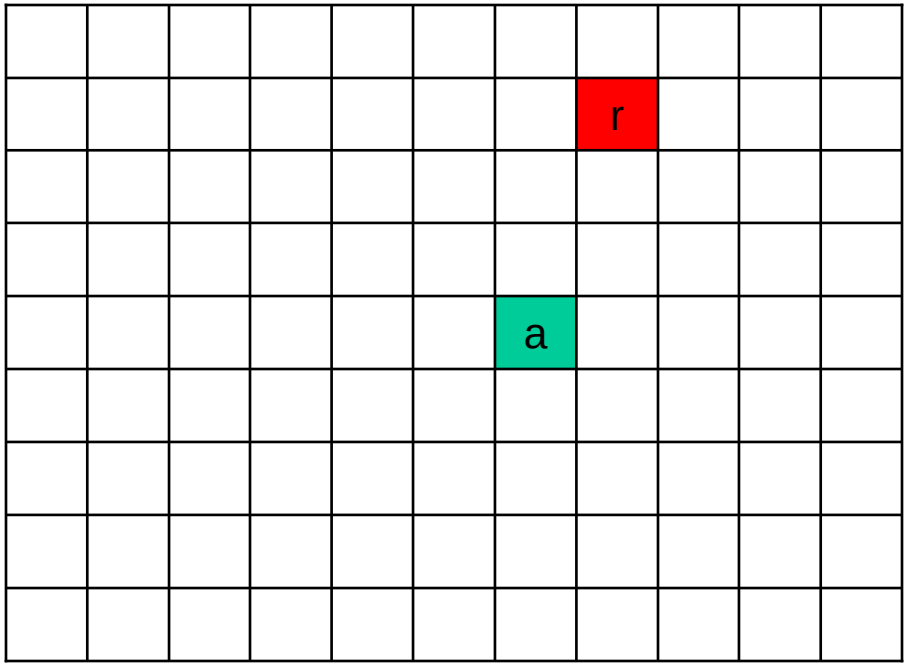


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations

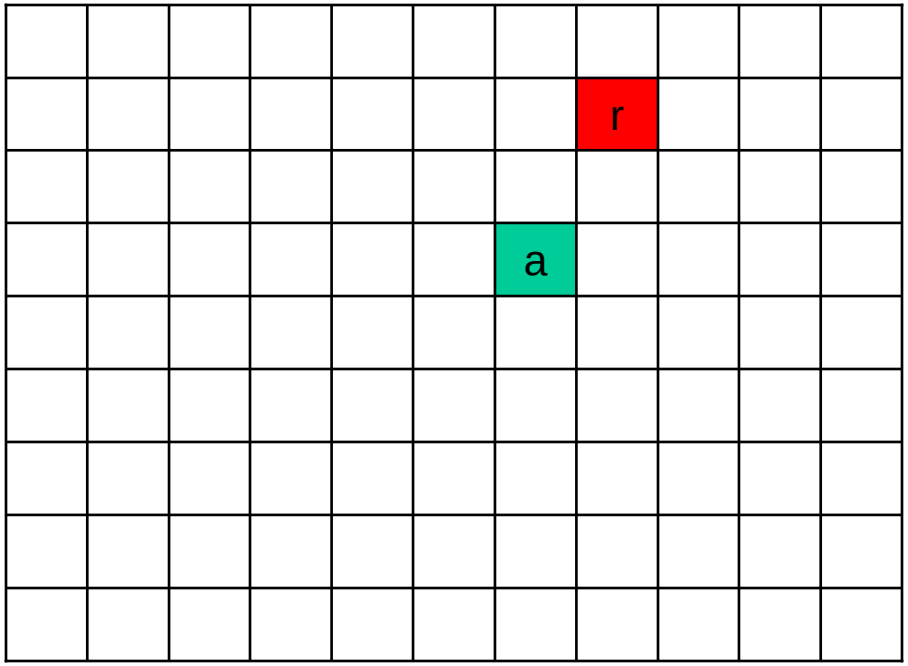


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations

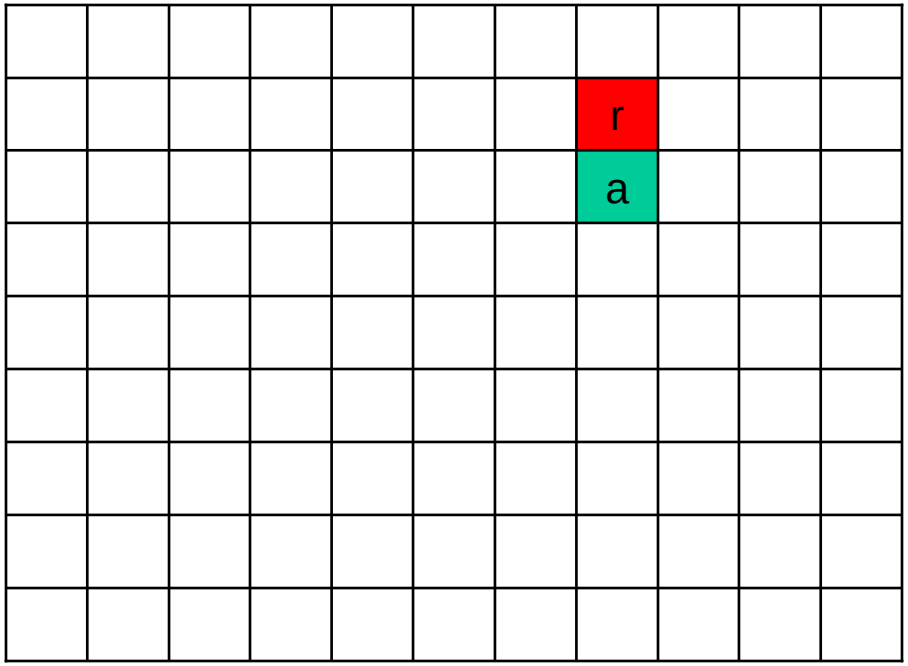


Memory stack:

1	(8,2)
2	empty

Addressing EPICURE issues

Solution: Use memory stack of goal locations



Memory stack:

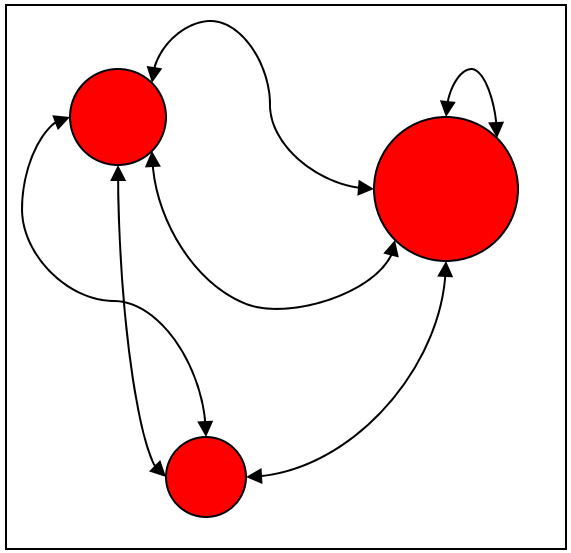
1	(8,2)
2	empty

Addressing EPICURE issues

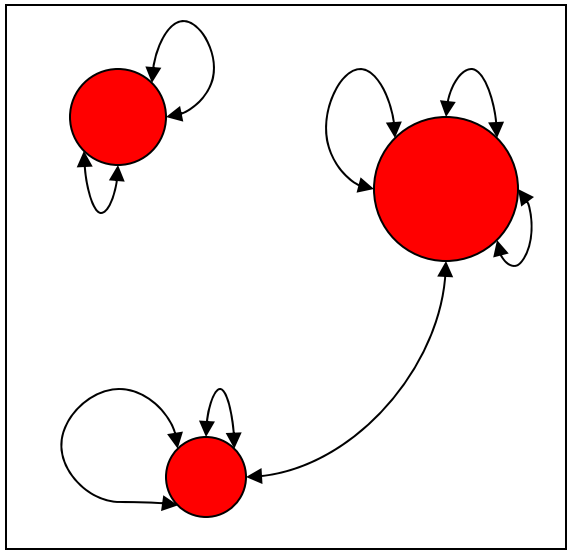
In EPICURE, exploratory agents were more "**jiggly**", not more exploratory

With the previously mentioned fixes, GEM agents that are more exploratory switch between resource options MORE often than exploitative agents

Exploratory Agent



Exploitative Agent



Travel path Resource patch

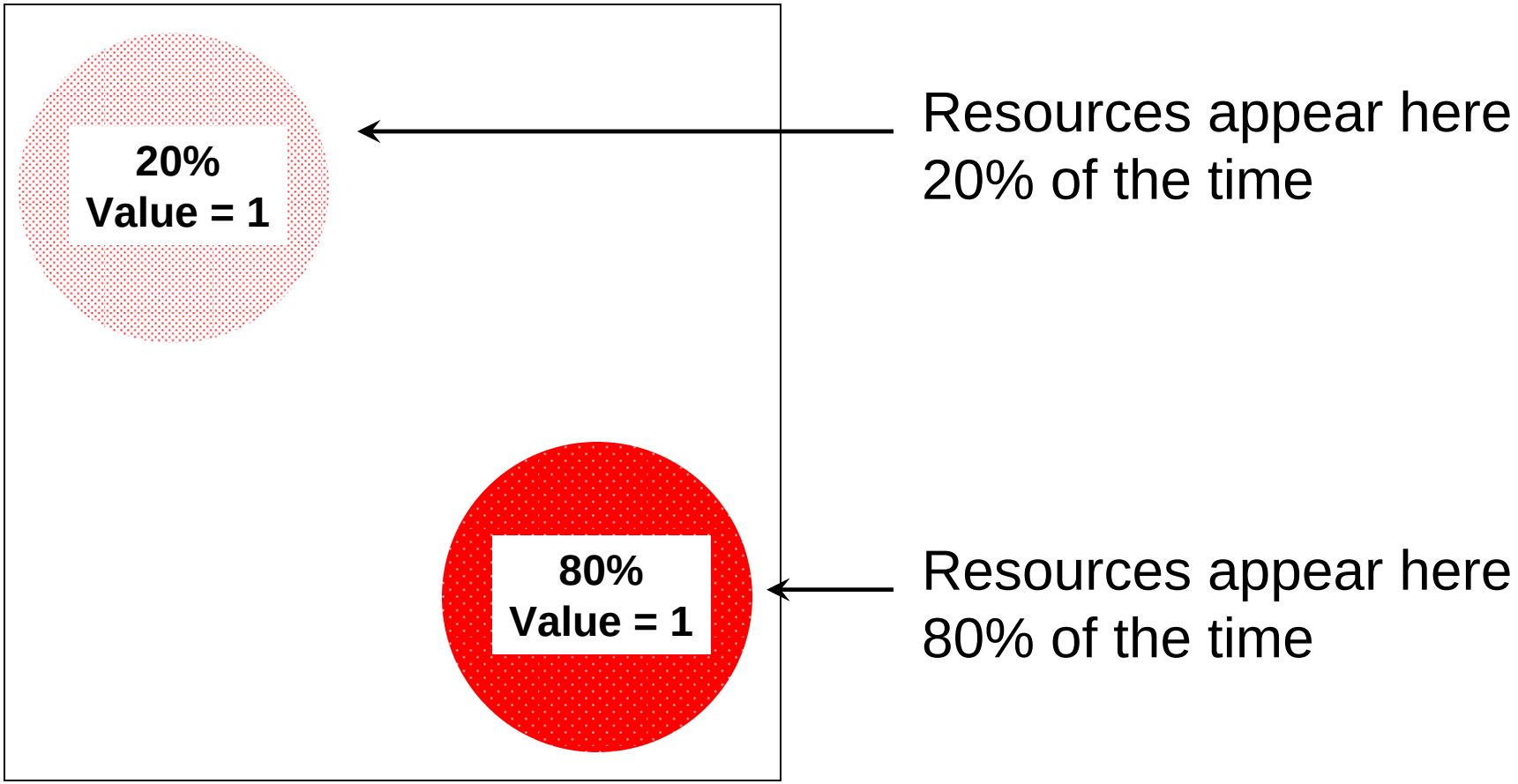
Using GEM to Characterize Human Behavior

Generalized Exploratory Model (GEM)

- Goal was to find an exploratory task and an exploitative task for human participants
- Used simulations in order to find them
- Exploitative task: Agents with LOW exploration parameter acquire more resources
- Exploratory task: Agents with HIGH exploration parameter aquire more resources

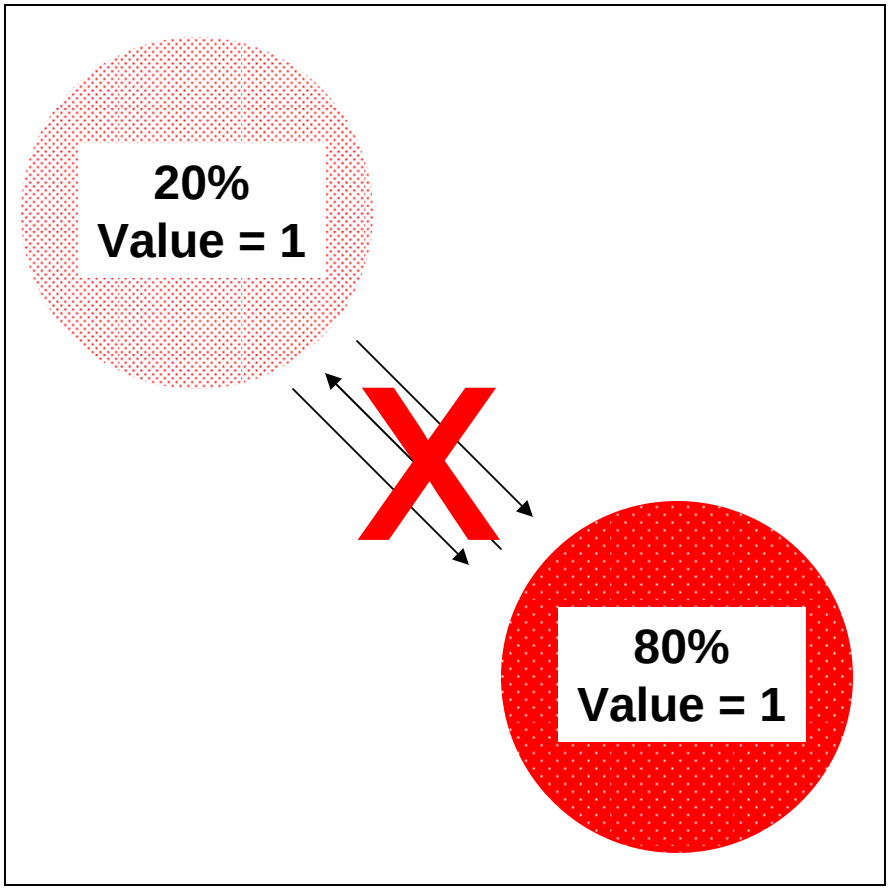
Generalized Exploratory Model (GEM)

- Exploitative task



Generalized Exploratory Model (GEM)

- Exploitative task

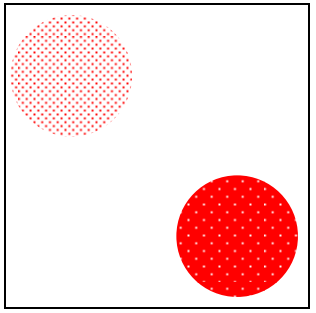


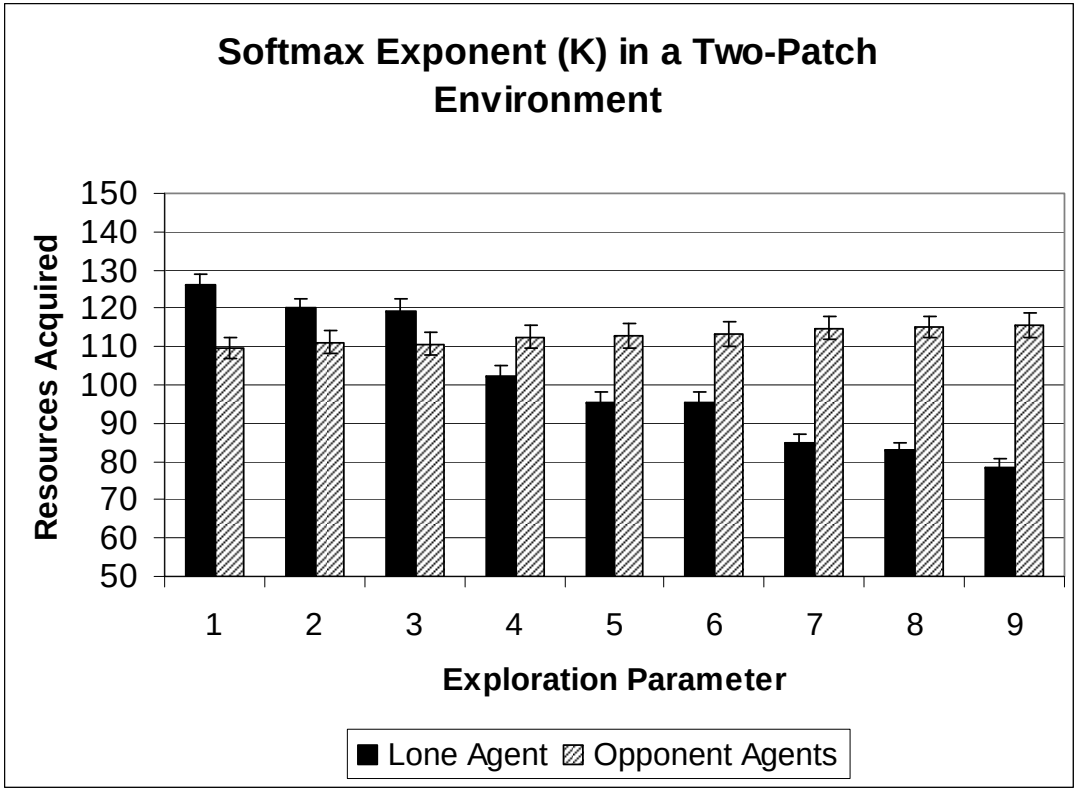
Why an exploitative task?

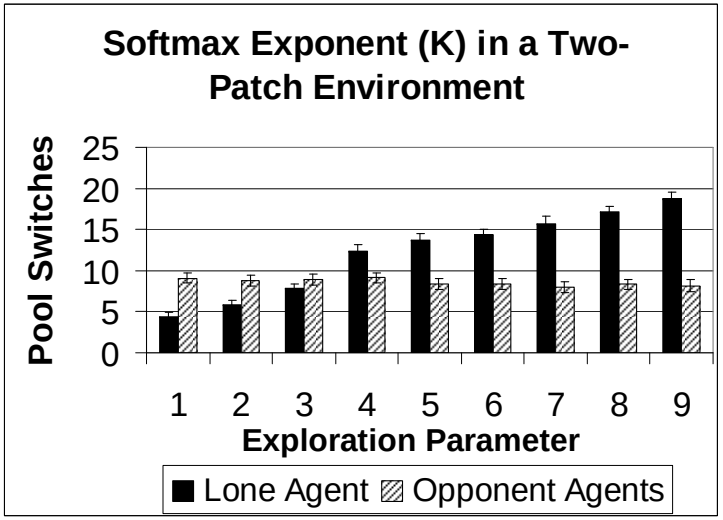
- Cost of switching
- Best to stay at one patch

Generalized Exploratory Model (GEM)

- Exploitative task – Simulation Results





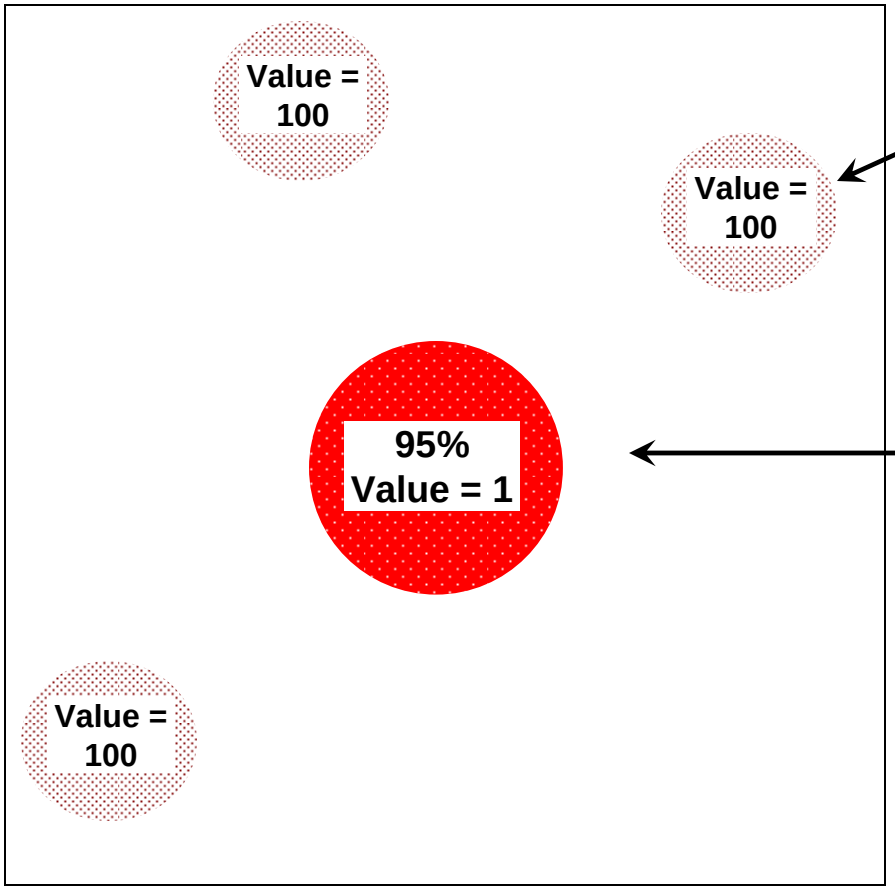


Generalized Exploratory Model (GEM)

Show example of Exploitative task

Generalized Exploratory Model (GEM)

- Exploratory task



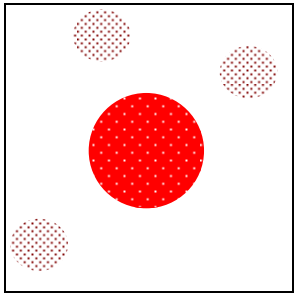
Resources appear at a small pool 5% of the time

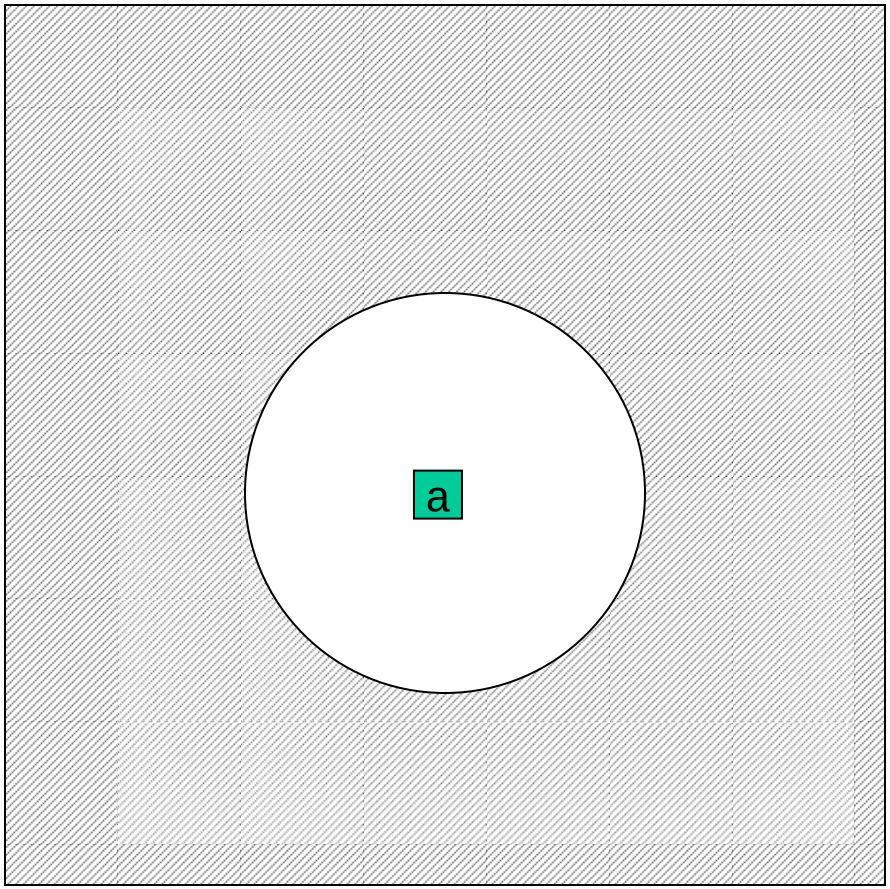
Resources appear here 95% of the time

Also…
Limited sight radius

Generalized Exploratory Model (GEM)

- Exploratory task





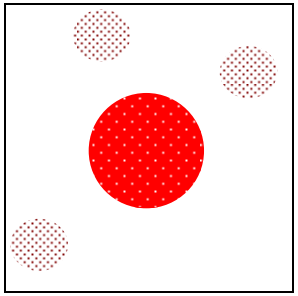
Limited sight radius

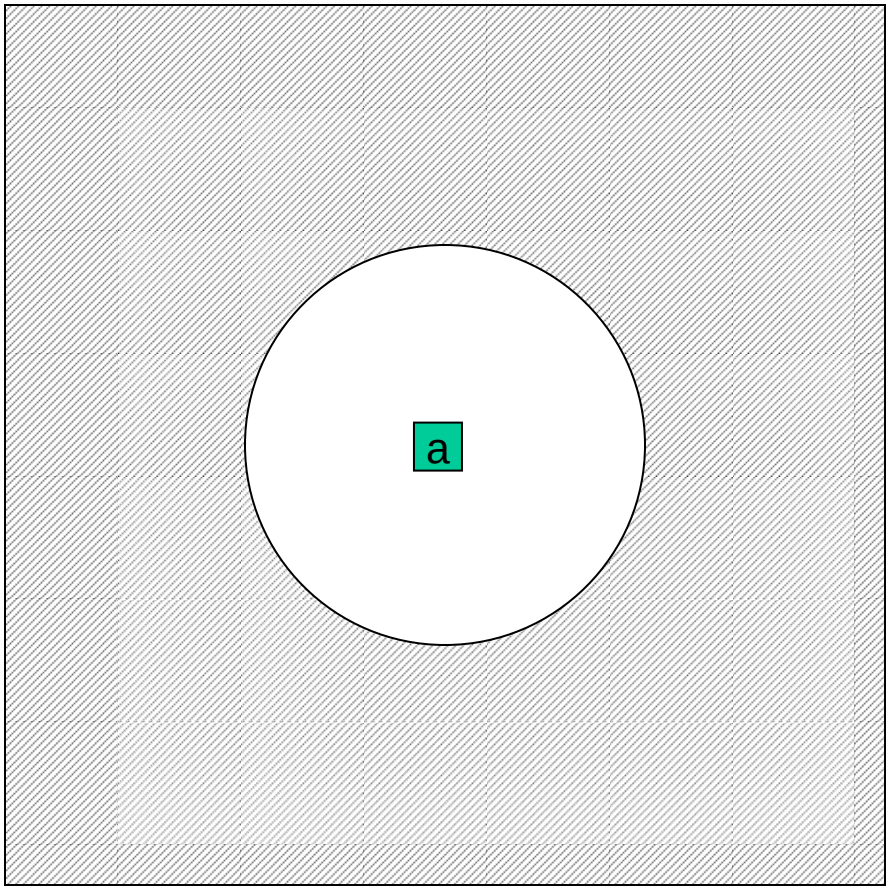
- View limited to 20 grid spaces away

- Must explore to find high valued resources

Generalized Exploratory Model (GEM)

- Exploratory task





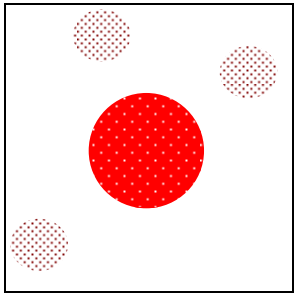
Limited sight radius

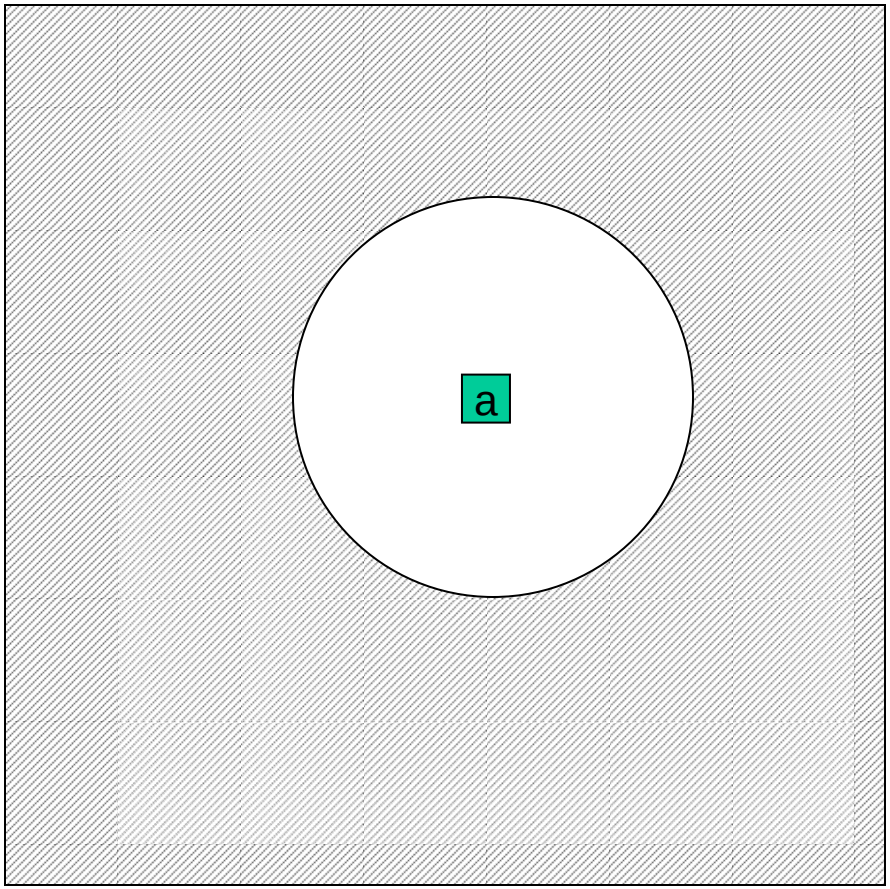
- View limited to 20 grid spaces away

- Must explore to find high valued resources

Generalized Exploratory Model (GEM)

- Exploratory task





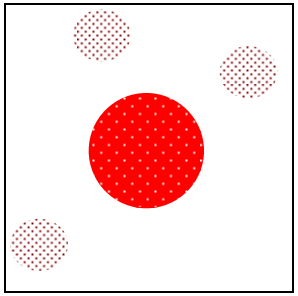
Limited sight radius

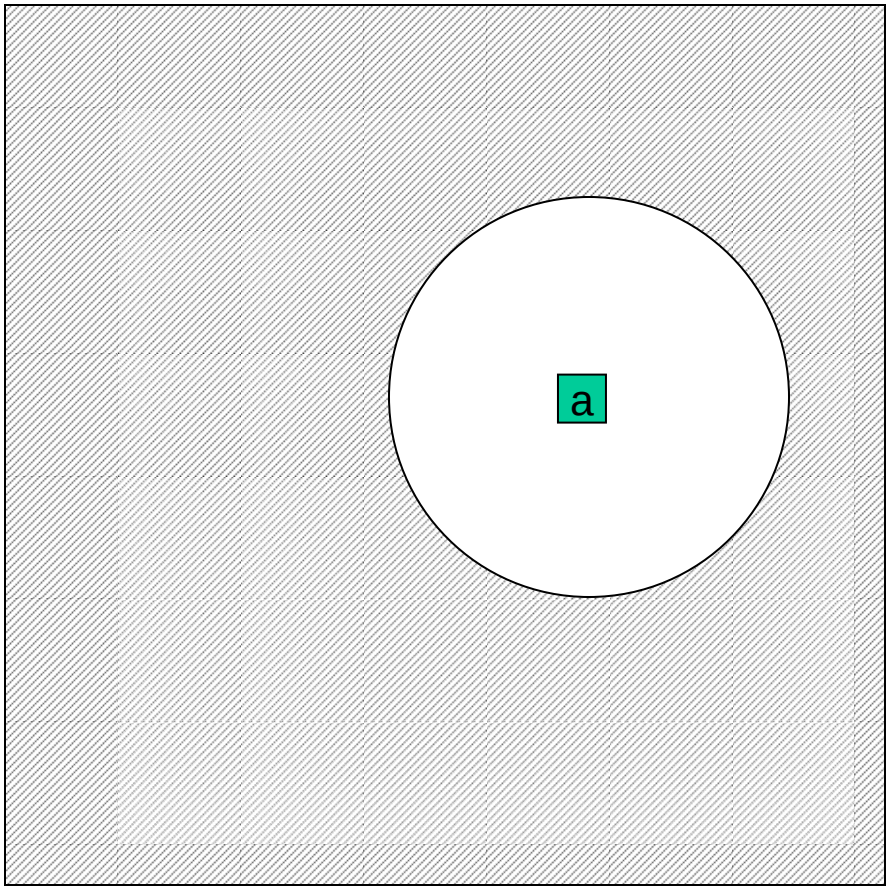
- View limited to 20 grid spaces away

- Must explore to find high valued resources

Generalized Exploratory Model (GEM)

- Exploratory task





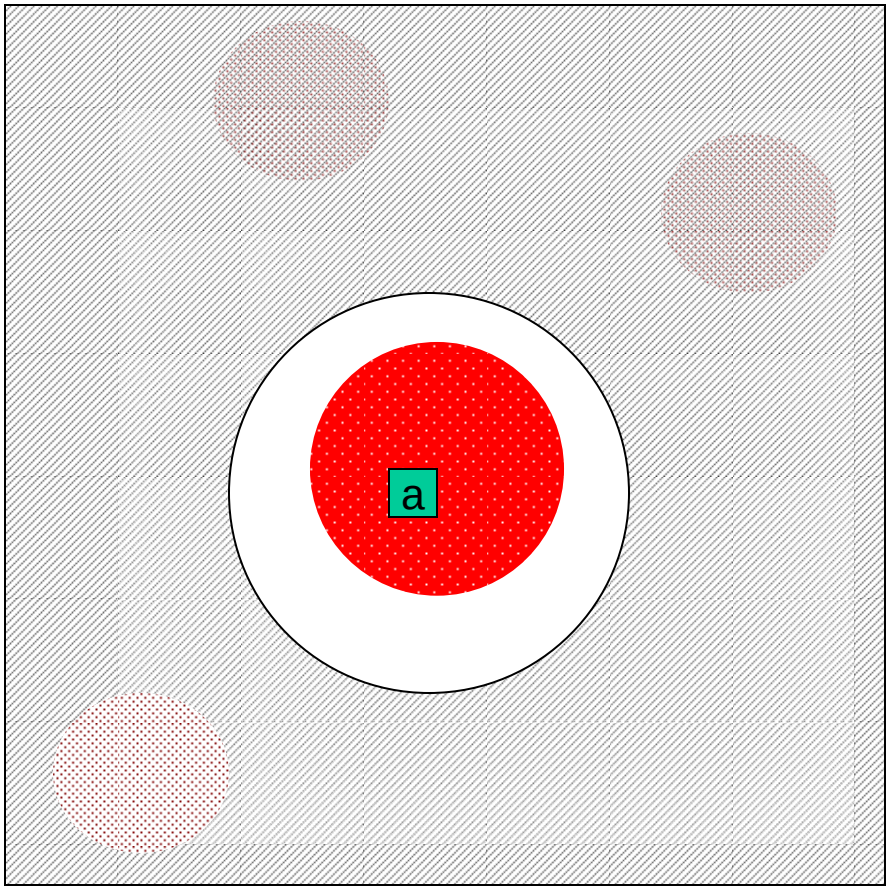
Limited sight radius

- View limited to 20 grid spaces away

- Must explore to find high valued resources

Generalized Exploratory Model (GEM)

- Exploratory task



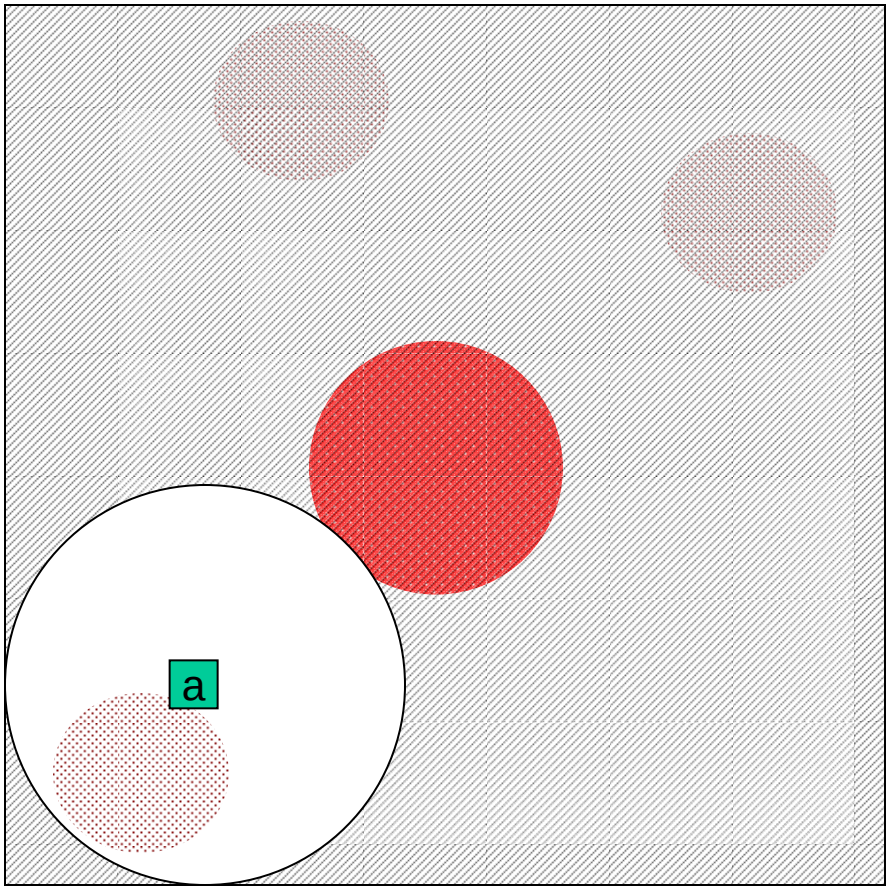
Why exploratory?

- Must explore the environment to find the high valued resources

- Must be willing to stop exploiting the central patch

Generalized Exploratory Model (GEM)

- Exploratory task



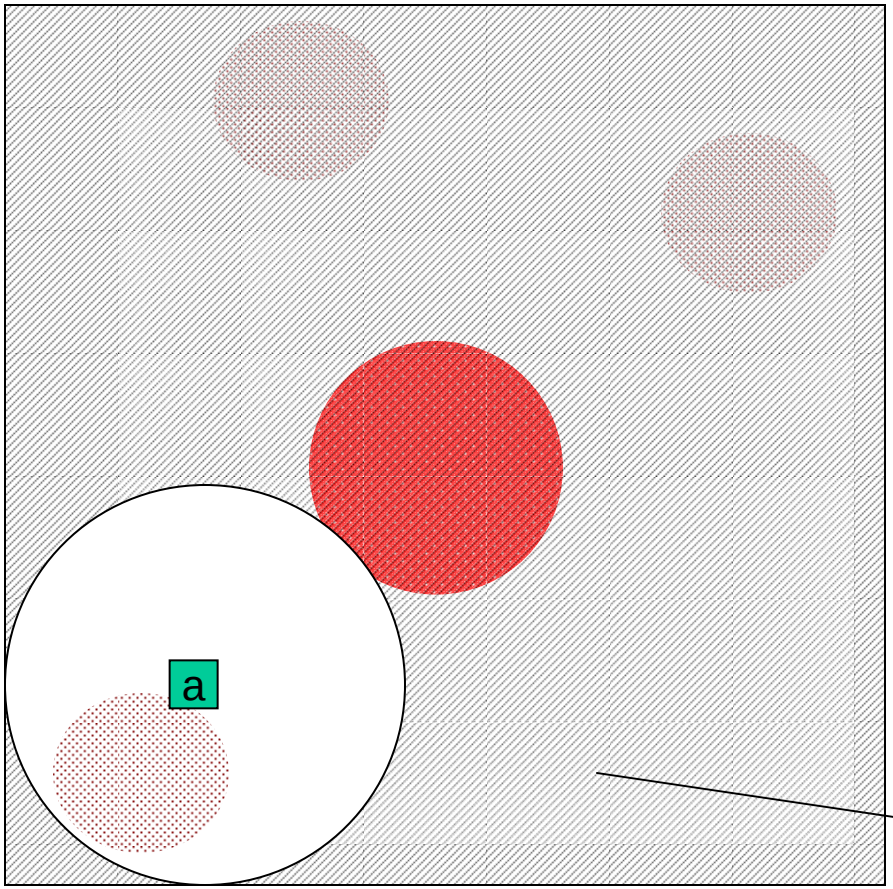
Why exploratory?

- Must explore the environment to find the high valued resources

- Must be willing to stop exploiting the central patch

Generalized Exploratory Model (GEM)

- Exploratory task



Why exploratory?

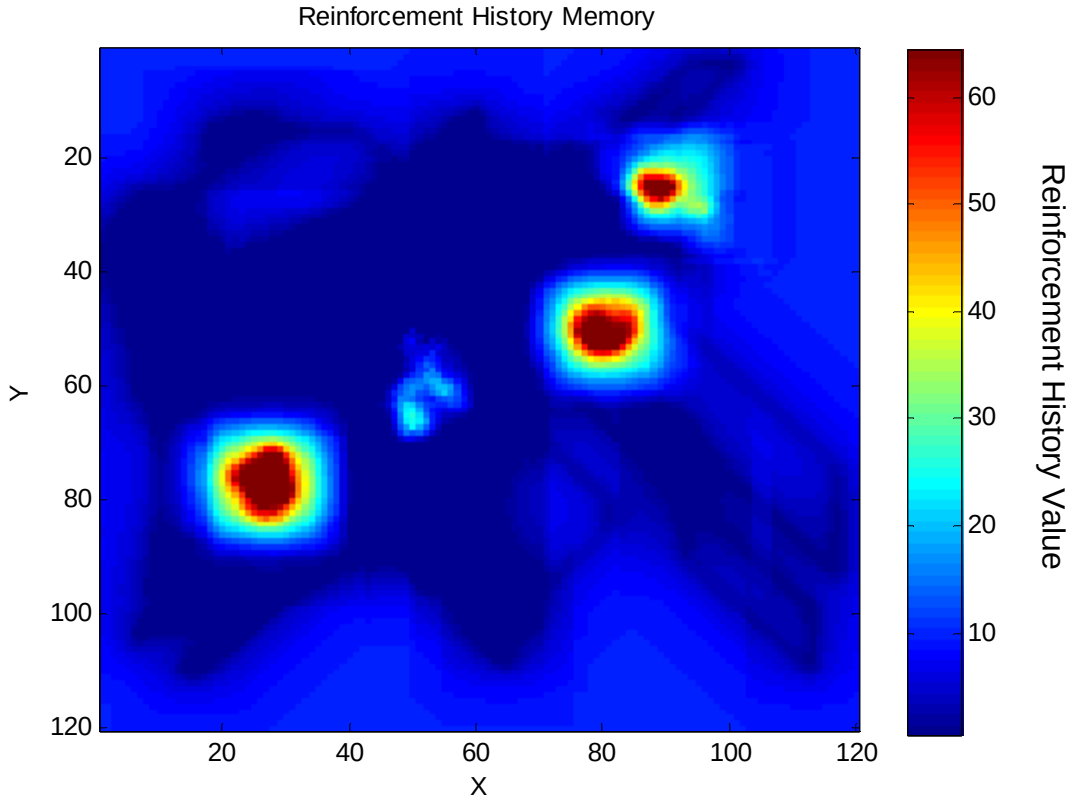
- Must explore the environment to find the high valued resources

- Must be willing to stop exploiting the central patch

Rely on reinforcement history memory for beyond radius

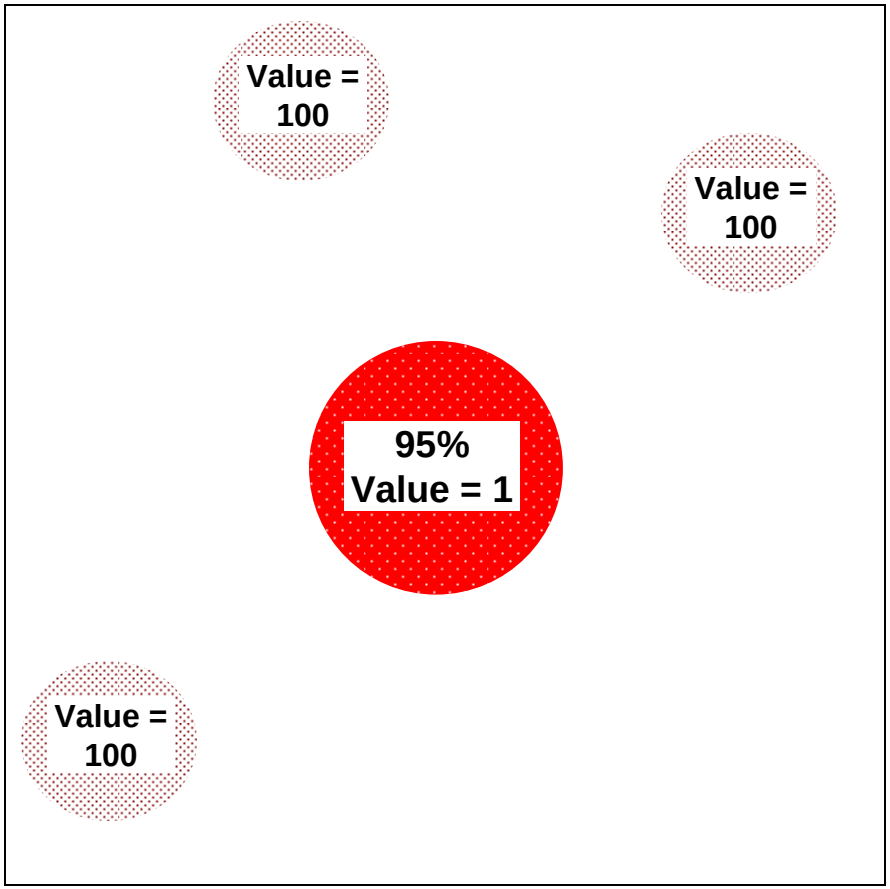
Generalized Exploratory Model (GEM)

- Reinforcement history memory



Generalized Exploratory Model (GEM)

- Exploratory task



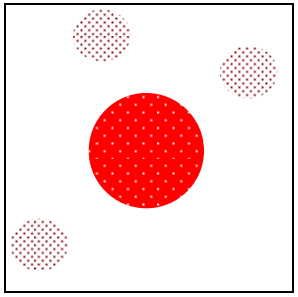
Why exploratory?

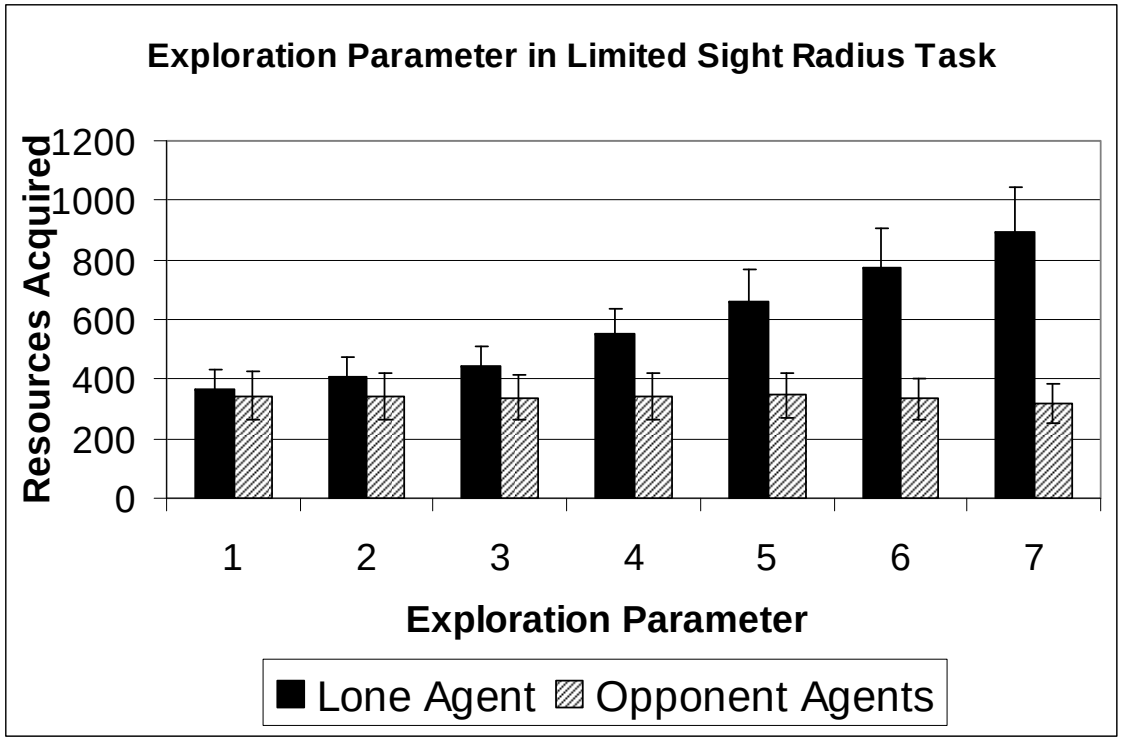
- Must explore the environment to find the high valued resources

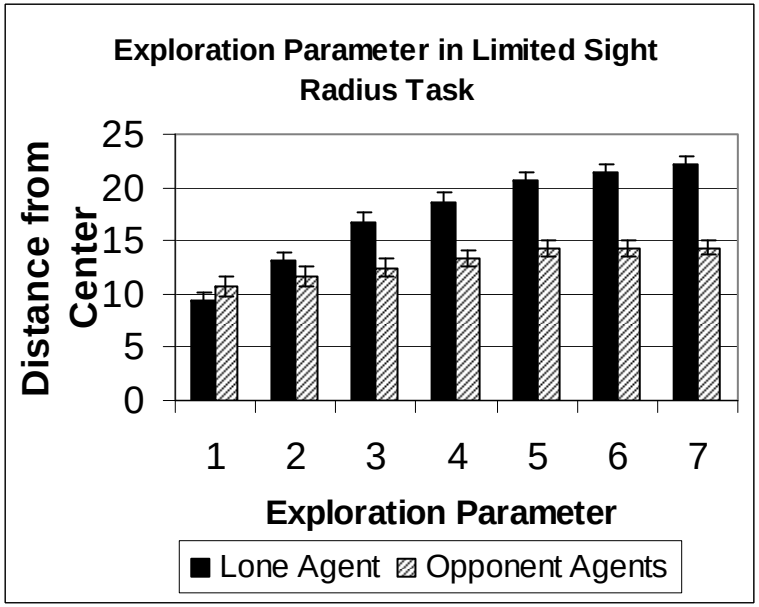
- Must be willing to stop exploiting the central patch

Generalized Exploratory Model (GEM)

- Exploratory task – Simulation Results







Generalized Exploratory Model (GEM)

Show example of Exploratory task

Understanding individual human foraging behavior with GEM

- Once we isolate features of agent behavior that lead to good/bad performance, we can use them to characterize human behavior

- Variety of possible dependent measures
  - Pool switches
  - Resources acquired
  - Distance from central pool
  - Effective speed
  - Changes in direction
  - Area covered

Understanding individual human foraging behavior with GEM

- Match subject's behavioral signature with simulated agents' signatures

Subject's Data

Switches	8
Resources acquired	52
Effective speed	4.3
Changes in direction	16

Exploitative Simulated Agent

Switches	2
Resources acquired	235
Effective speed	2.2
Changes in direction	37

Exploratory Simulated Agent

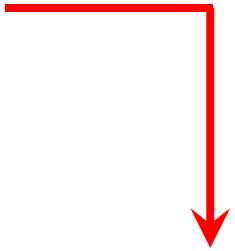
Switches	9
Resources acquired	78
Effective speed	4.8
Changes in direction	18

Understanding individual human foraging behavior with GEM

- Match subject's behavioral signature with simulated agents' signatures

Subject's Data

Switches	8
Resources acquired	52
Effective speed	4.3
Changes in direction	16



Exploitative Simulated Agent

Switches	2
Resources acquired	235
Effective speed	2.2
Changes in direction	37

Exploratory Simulated Agent

Switches	9
Resources acquired	78
Effective speed	4.8
Changes in direction	18

An Application of GEM:

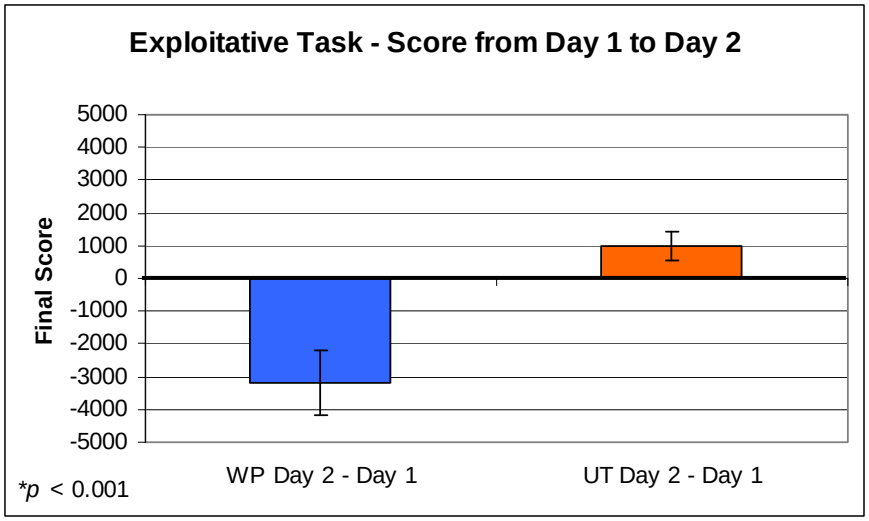
Exploration/Exploitation in Fatigued Subjects

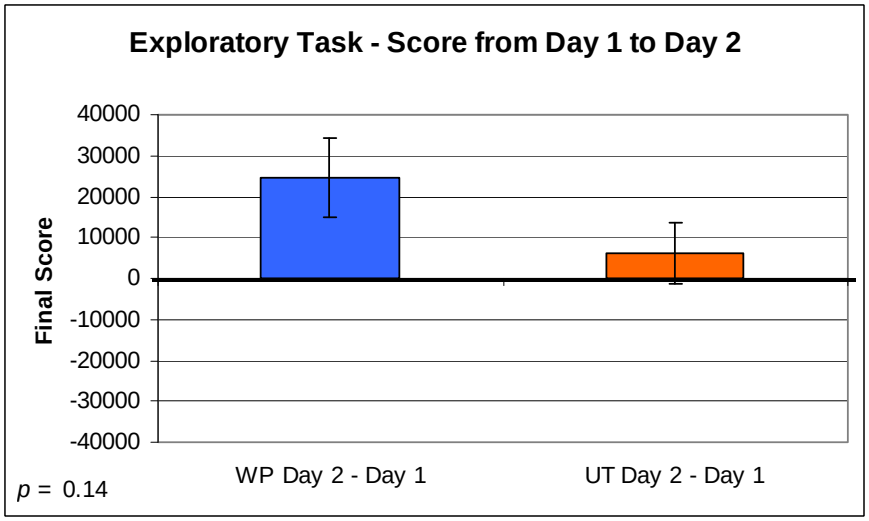
Application of GEM to Studying Exploration/Exploitation in Fatigue

	Day 1	Day 2
West Point Cadets	Fresh	**Fatigued**
UT Undergraduates	Fresh	Fresh

Each Day: 3 Exploitative Tasks and 3 Exploratory Tasks

Application of GEM to Studying Exploration/Exploitation in Fatigue





- Might expect performance deficit across the board when fatigued

- On Day 2, fatigued West Point Cadets acted more like a simulated agent with a high Exploration parameter
  - ✓ Performed better on the Exploration task
  - ✓ Performed worse on the Exploitation task

from Glass, Maddox, Markman, Schnyer & Kornguth (Manuscript in Preparation)

Application of GEM to Studying Exploration/Exploitation in Fatigue

Sample of characterizing subject performance using the output of GEM simulations

(One task that pushes subject to be exploratory, one that pushes subject to be exploitative.)

from Glass, Maddox, Markman, Schnyer & Kornguth (Manuscript in Preparation)

Understanding individual human foraging behavior with GEM

- Exploration task

WP Fatigued – Day 2

Distance from Center	33.6
Resources Acquired	1011
Effective speed	4.3

Exploitative Simulated Agent

Distance from Center	9
Resources Acquired	280
Effective speed	3.3

Exploratory Simulated Agent

Distance from Center	22
Resources Acquired	850
Effective speed	4.1

Understanding individual human foraging behavior with GEM

- Exploitative task

UT Control – Day 2

Patch switches	1
Resources Acquired	133
Effective speed	3.2

Exploitative Simulated Agent

Patch switches	3
Resources Acquired	125
Effective speed	3.3

Exploratory Simulated Agent

Patch switches	16
Resources Acquired	68
Effective speed	4.3

Concluding Remarks

Concluding Remarks

- Human foraging excellent for studying the exploration / exploitation tradeoff

- 2D EPICURE model modified / upgraded
  - More ecological validity
  - Ability for human participants to compete against simulated agents

- Example of an application of the model to study of fatigue

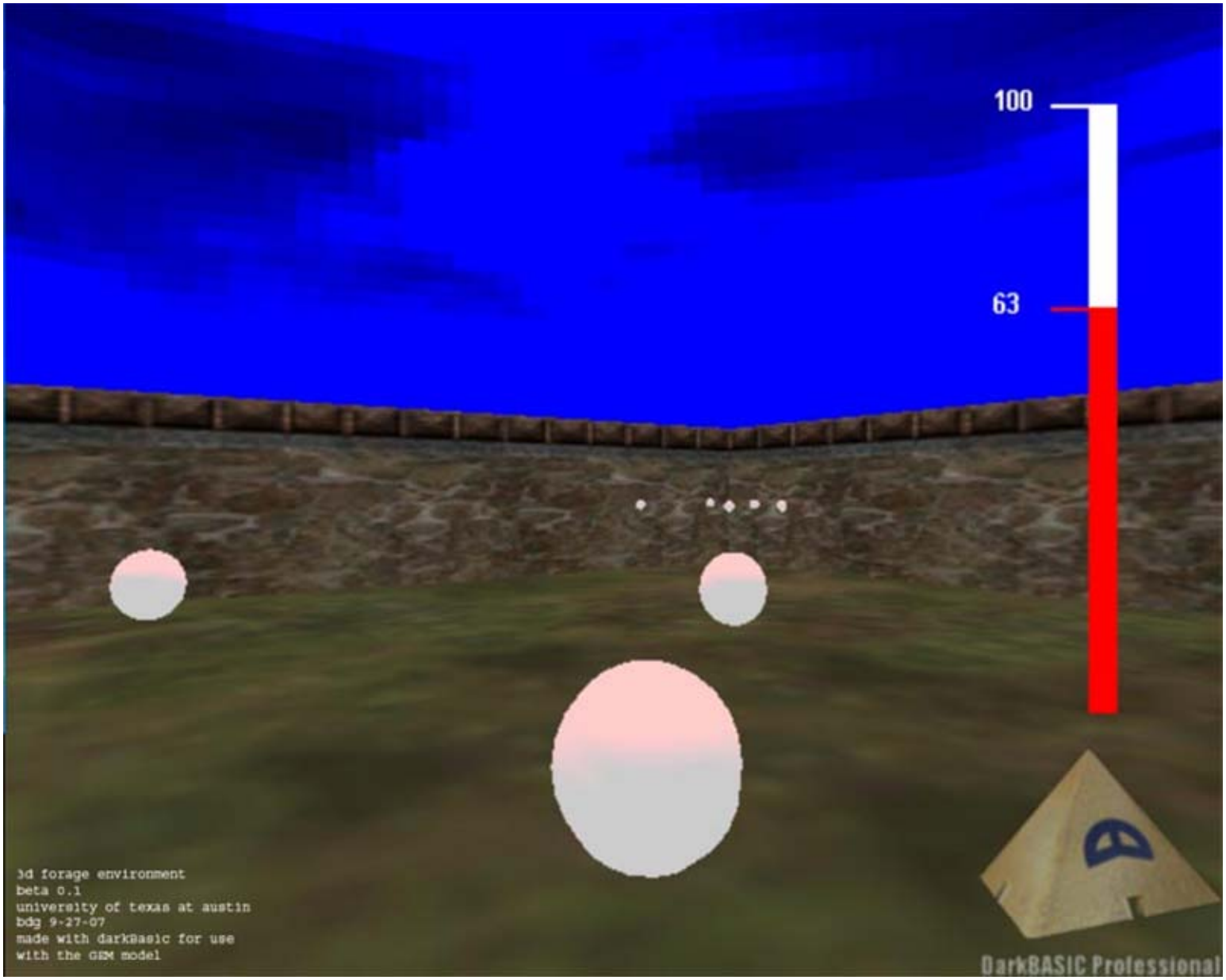
- Future directions
  - Motivational influences (Regulatory Focus)
  - 3D task
  - Tons of environments possible
  - Tons of manipulations possible
  - fMRI – new way to determine brain states associated with exploration / exploitation

Other Current Projects

- Motivation and learning interface
  - Signal detection task – sensitivity and response bias
  - Cognitive flexibility – set shifting
    - Wisconsin Card Sorting Task (WCST)

- Category learning
  - Extra-dimensional and intra-dimensional shifts
  - Feedback effects

- Ego-depletion and aggression


100
63
3d forage environment
beta 0.1
university of texas at austin
bdg 9-27-07
made with darkBasic for use
with the GEM model
DarkBASIC Professional