Pedestrian Evacuation Dynamics in Public Spaces

Understanding the Impact of Environmental Familiarity and Intervention Strategies

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(Group 13)

01

Introduction

Problem description and importance of the research

Escalating Challenges in Public Space Evacuations

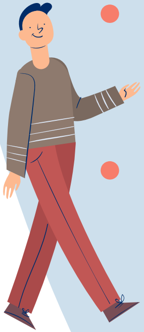
- Rising Attendance
- Crowded Environments *(Lui, 2018)*
- High density risks
- Catastrophic incidents may occur *(Yuan and Tan, 2009)*

Figure 1. *Freepik. (n.d.). A large crowd of people inside a mall. Freepik. https://www.freepik.com/premium-photo/large-crowd-people-inside-mall_2386643861.htm*

Research question:

How do varying levels of environmental familiarity and the implementation of intervention strategies influence the speed of crowd evacuations in public spaces under an emergency situation?

Emerging behaviour



- Activation and movement
  - Attraction towards exits
- Social force *(Helbing and Molnar, 1995)*
  - Repulsion
- Novelty of our model:
  - Environmental familiarity → Knowledge spread

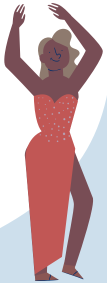
Importance of an agent-based modelling approach

- Complexity and heterogeneity of Pedestrian Behavior
  - Knowledge variance
  - Social preferences
- Interaction between individuals
- Influencing external factors/ environment
- Spatial localization

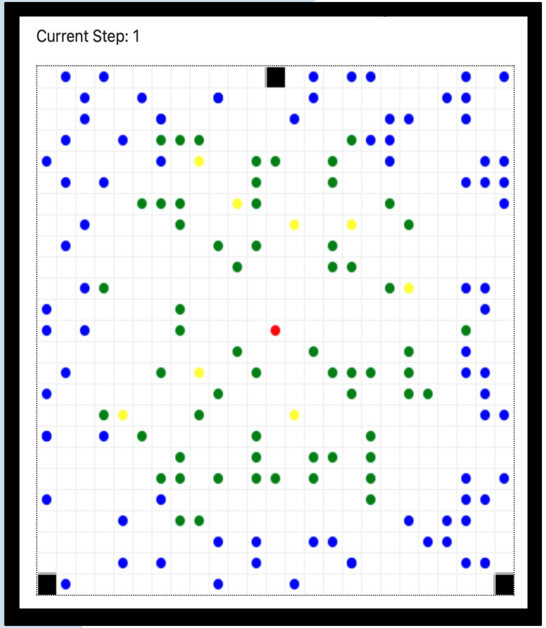
(Bonabeau, 2002; Zia and Ferscha, 2020)

02

Model implementation

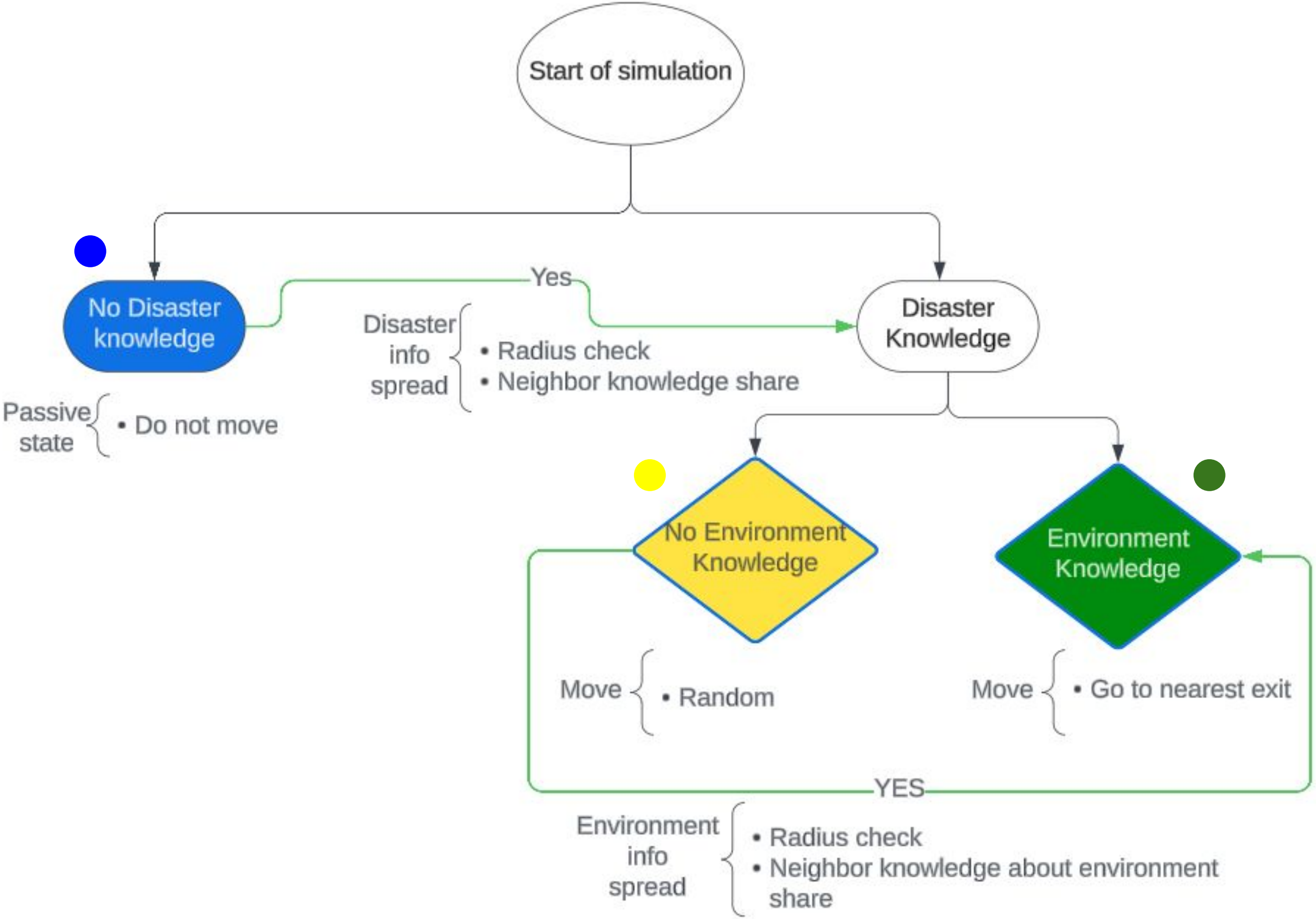


Model description



Disaster

Exit



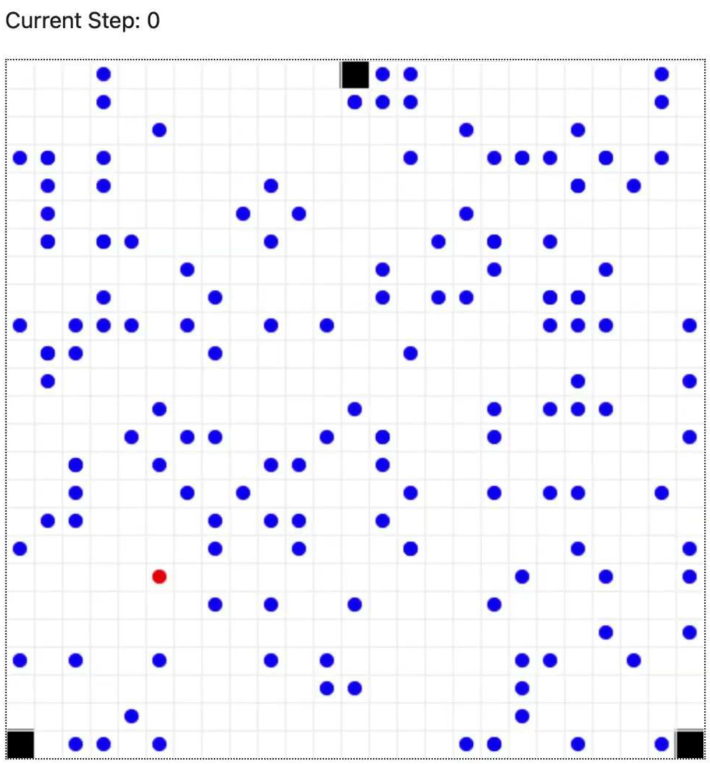
Movement of agents

- Attraction to one exit
- Social repulsion force

$$\begin{cases} \frac{dx}{dt} & = v \\ \frac{dv}{dt} & = F_{goal} + F_{social} \end{cases}$$

$$F_{goal} = (\vec{v}^0(t)\vec{e}^0(t) - \vec{v}(t))/\tau$$
$$F_{social} = -\nabla_{\vec{r}_{\alpha\beta}} \exp(-b(\vec{r}_{\alpha\beta}))$$

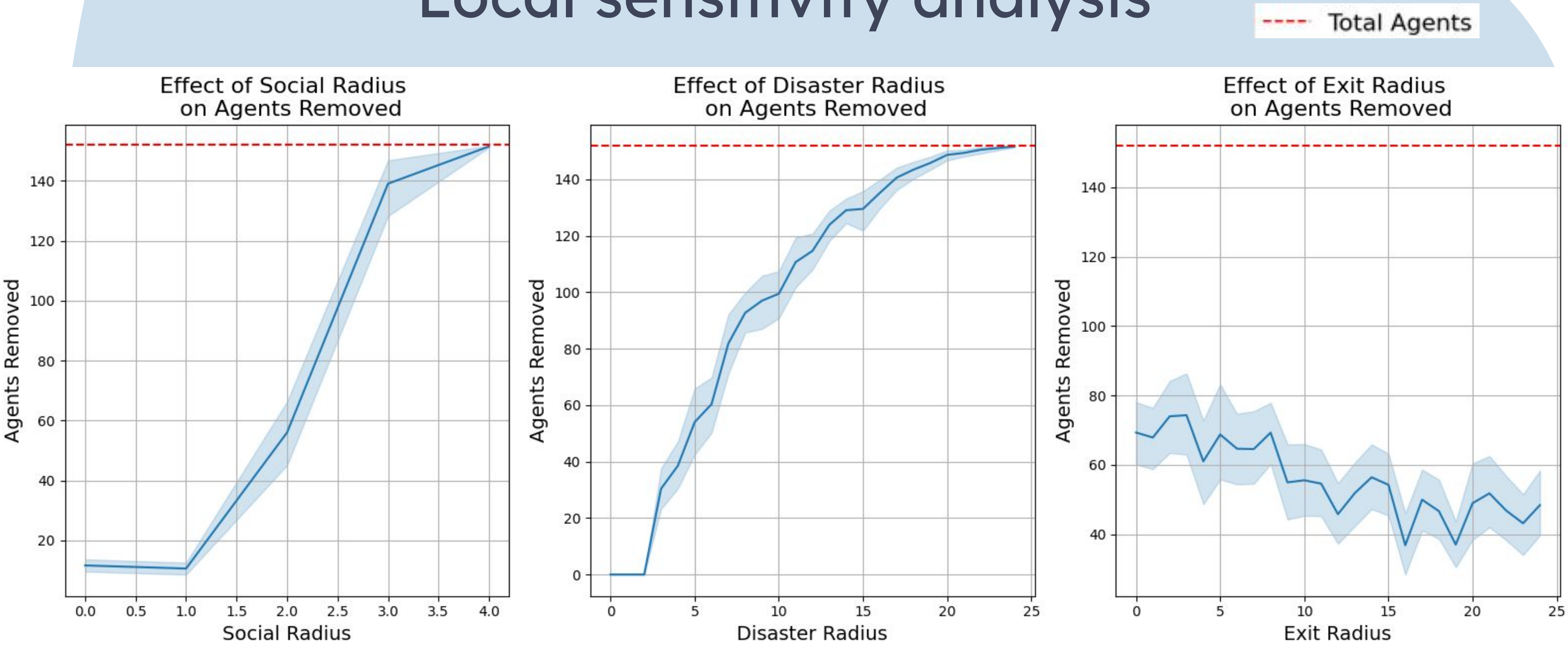
$$2b := \sqrt{(||\vec{r}_{\alpha\beta}|| + ||\vec{r}_{\alpha\beta} - v_\beta \Delta t \vec{e}_\beta||)^2 - (v_\beta \Delta t)^2}$$



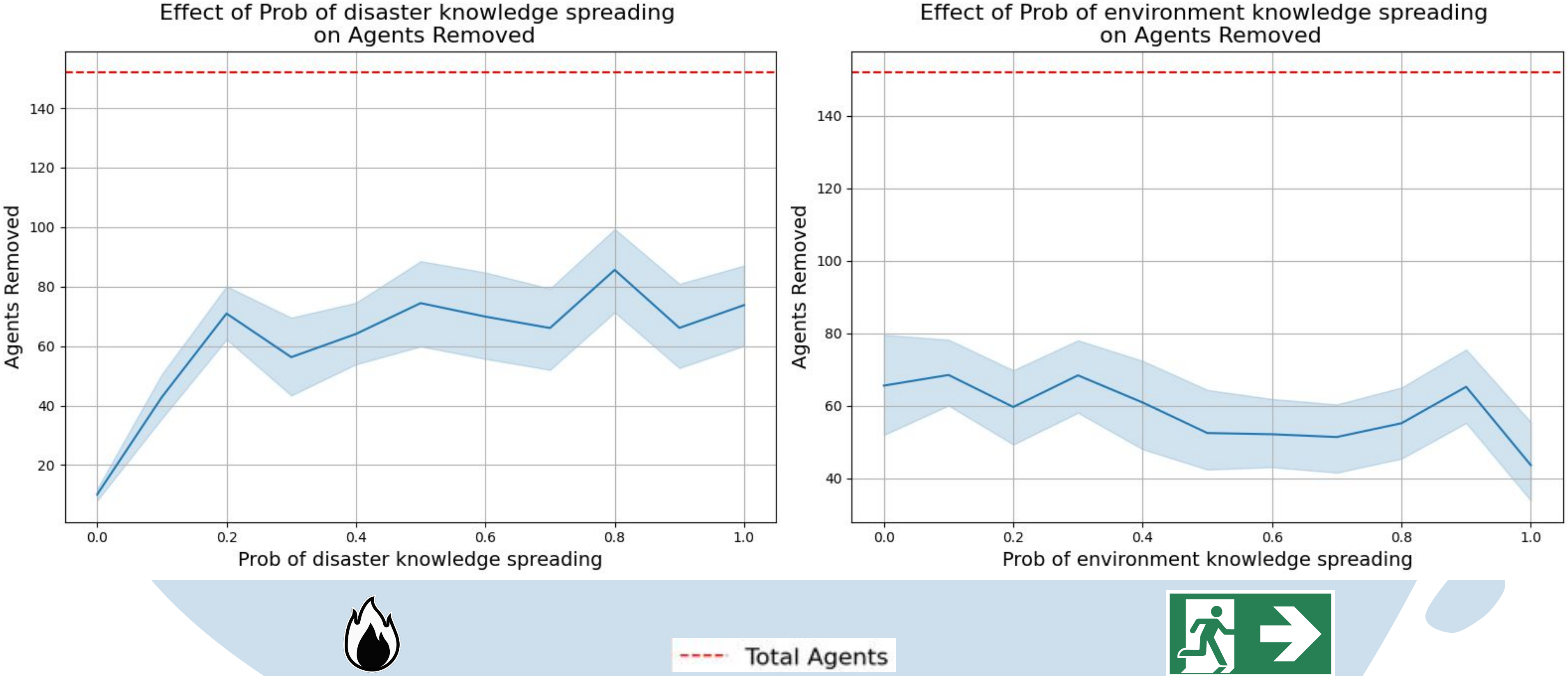
03

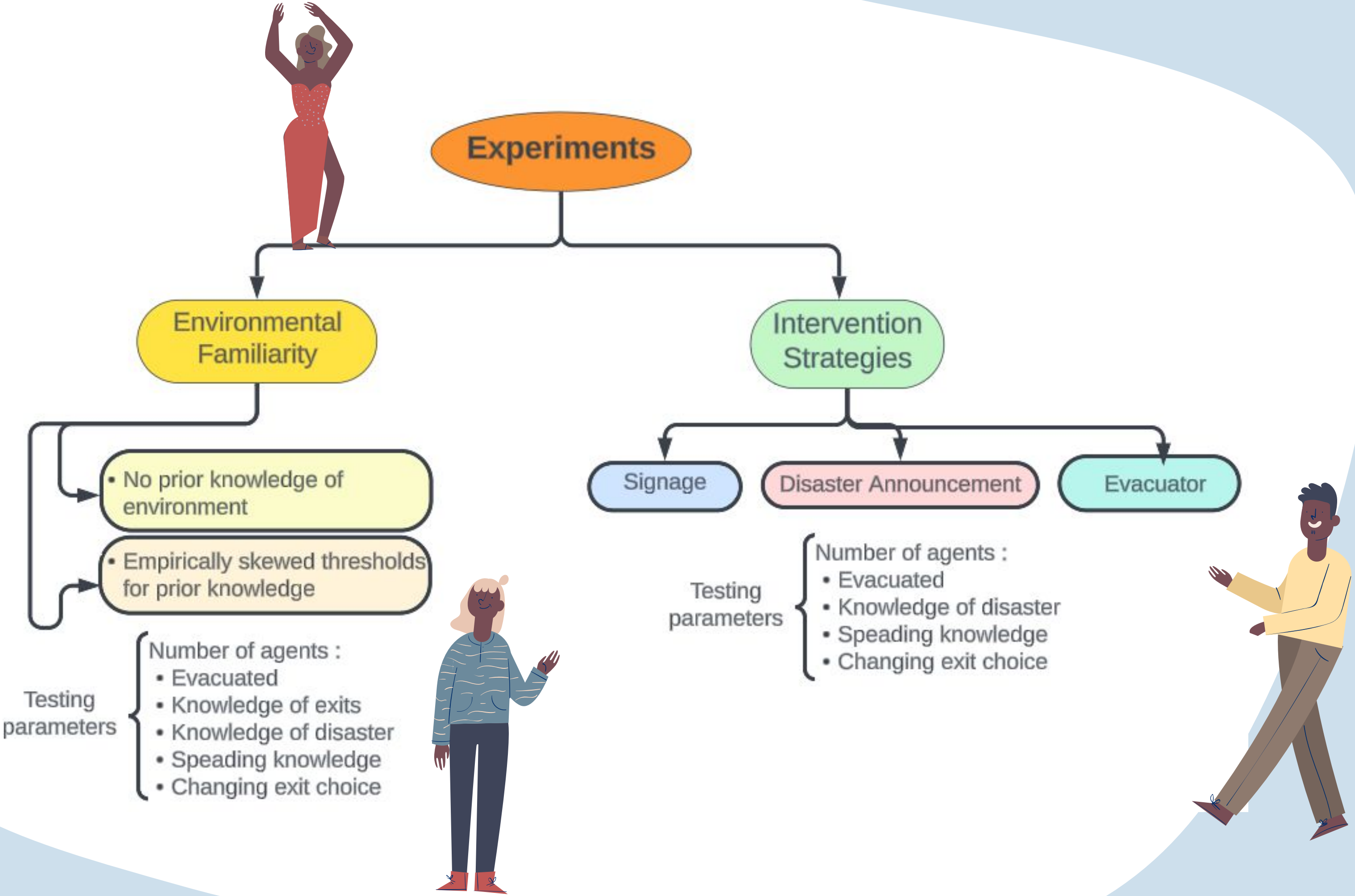
Experimental setup and Results

Local sensitivity analysis



Local sensitivity analysis




Experiments
Environmental Familiarity
Intervention Strategies
• No prior knowledge of environment
• Empirically skewed thresholds for prior knowledge
Testing parameters
Number of agents :
• Evacuated
• Knowledge of exits
• Knowledge of disaster
• Speading knowledge
• Changing exit choice
Signage
Disaster Announcement
Evacuator
Testing parameters
Number of agents :
• Evacuated
• Knowledge of disaster
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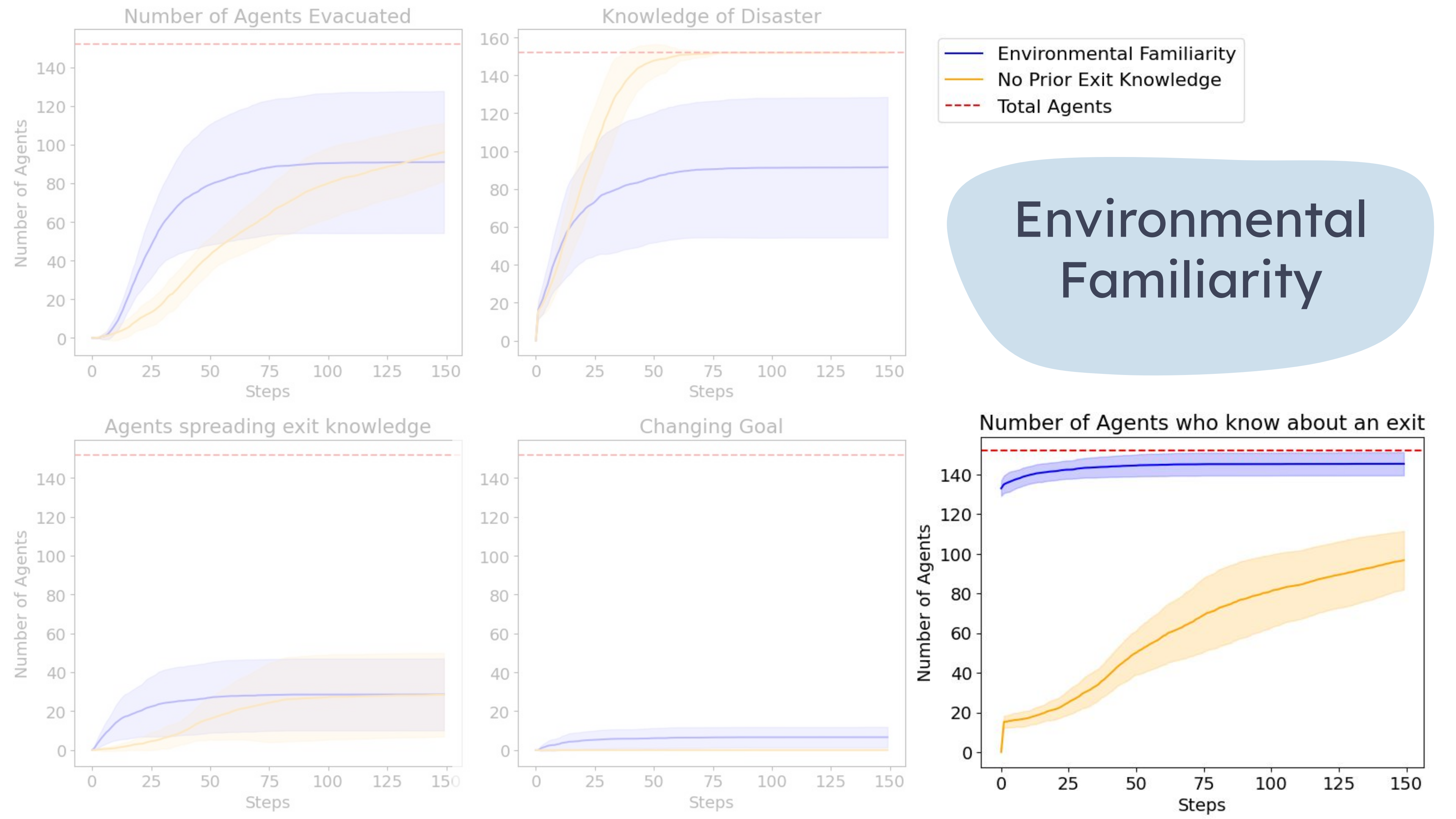
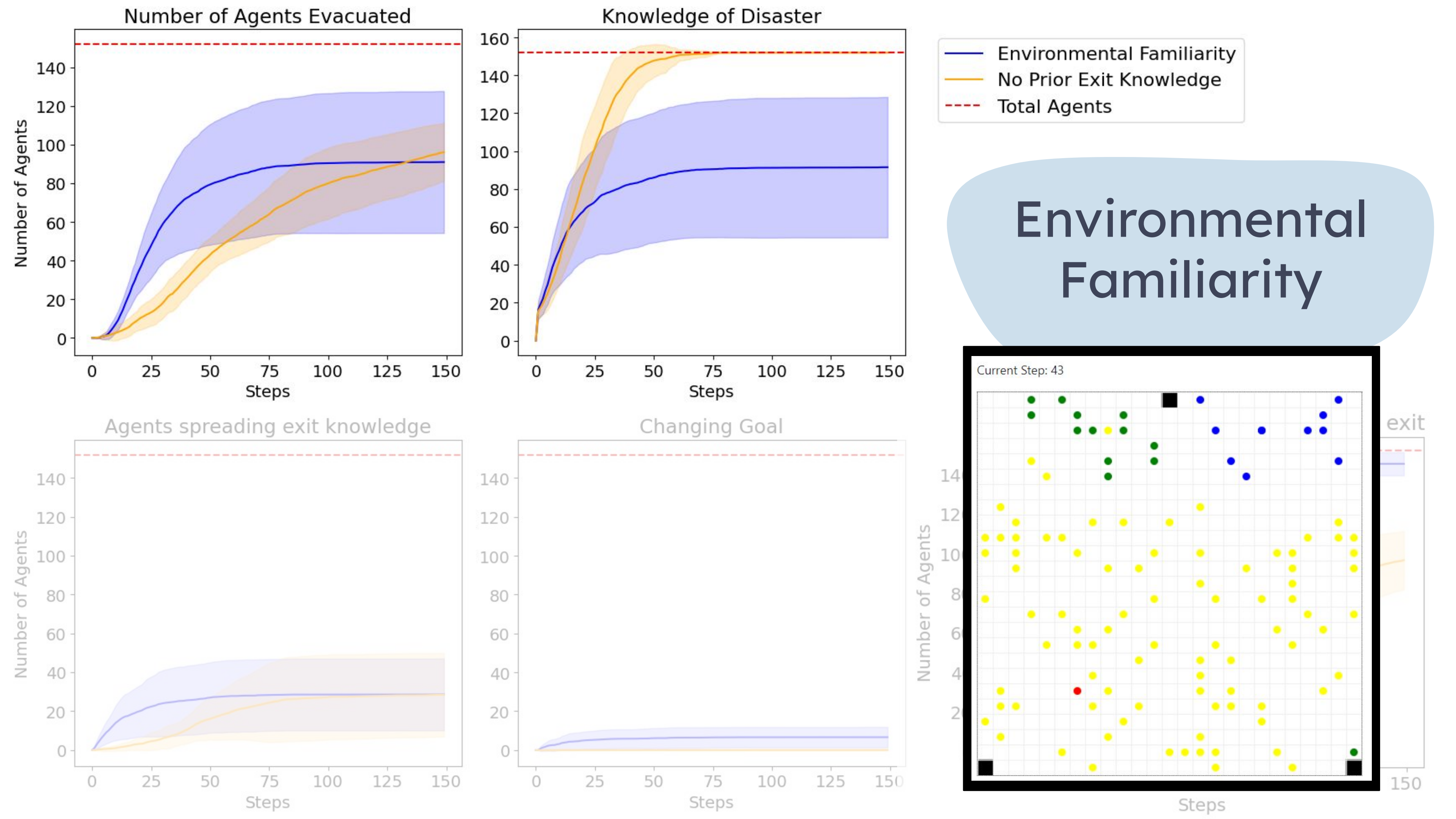
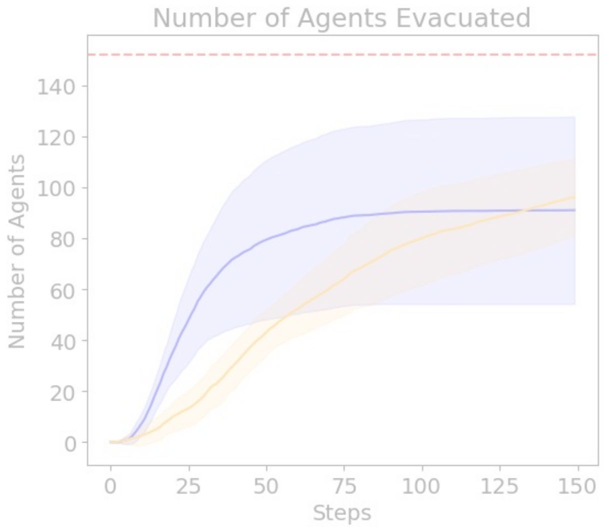
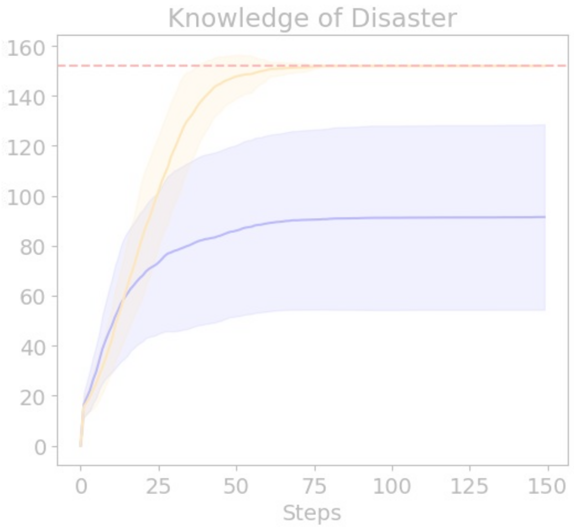
• Changing exit choice

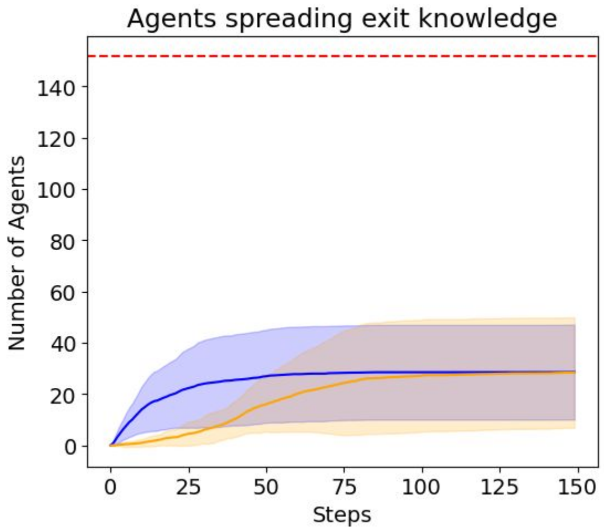

Environmental Familiarity
Number of Agents Evacuated
Knowledge of Disaster
Agents spreading exit knowledge
Changing Goal
Number of Agents who know about an exit
Number of Agents
Steps
Environmental Familiarity
No Prior Exit Knowledge
Total Agents

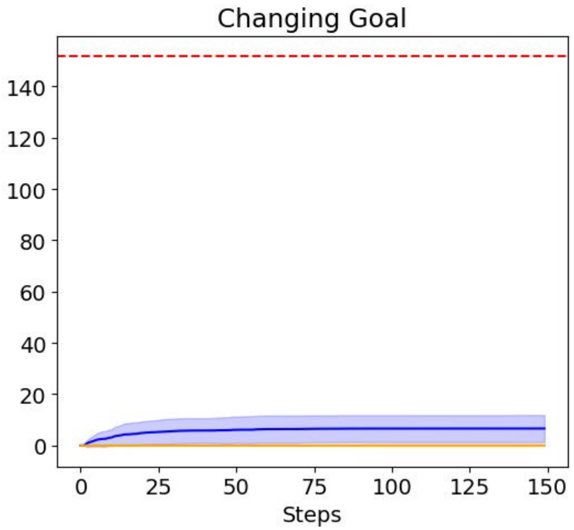

Number of Agents Evacuated
Knowledge of Disaster
Number of Agents
Steps
Environmental Familiarity
No Prior Exit Knowledge
Total Agents
Environmental
Familiarity
Current Step: 43
Agents spreading exit knowledge
Changing Goal
exit

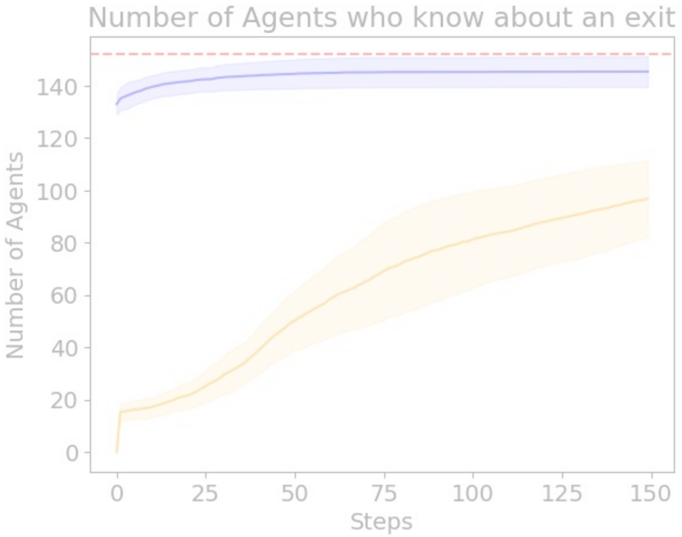


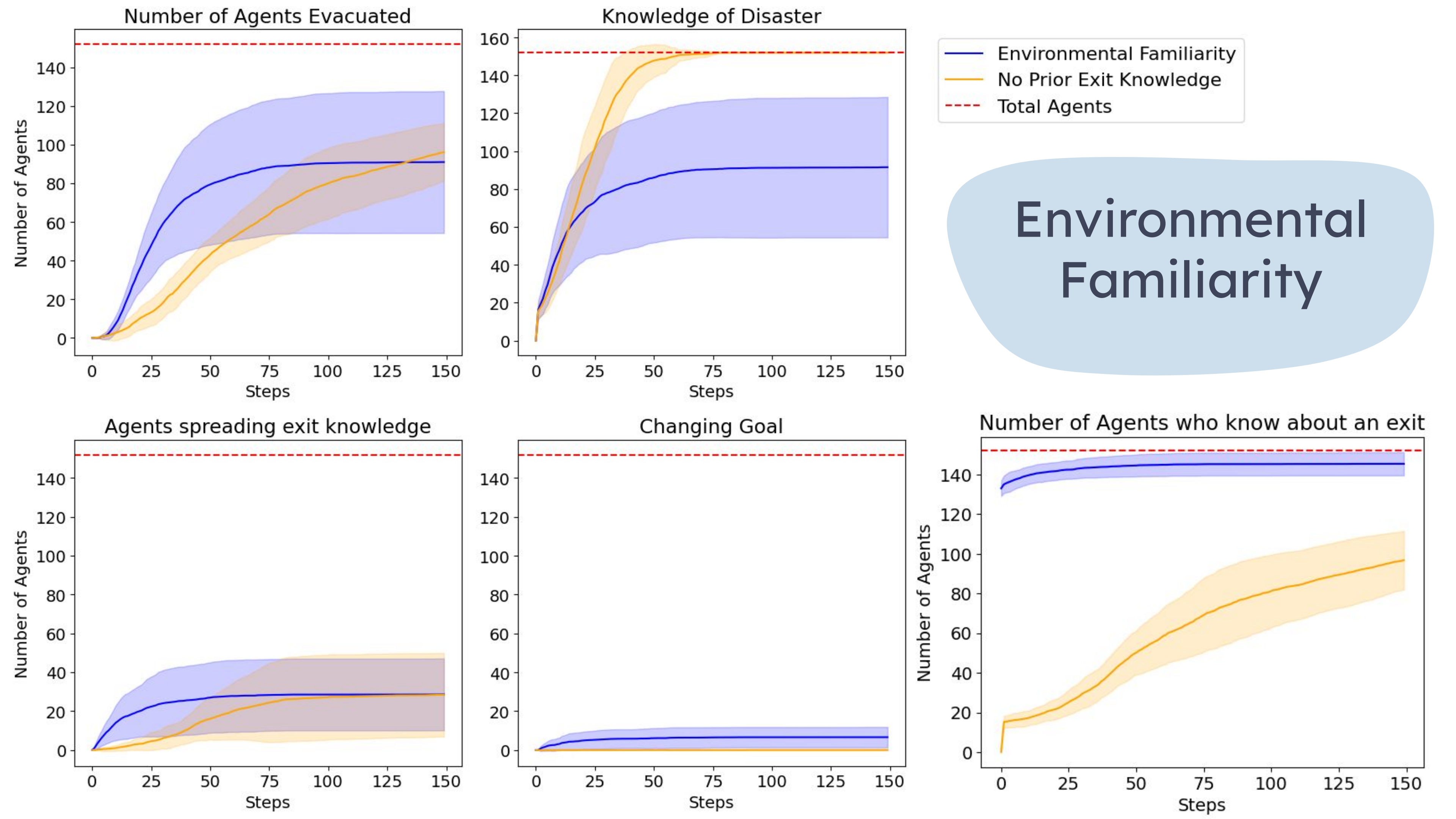


Environmental Familiarity

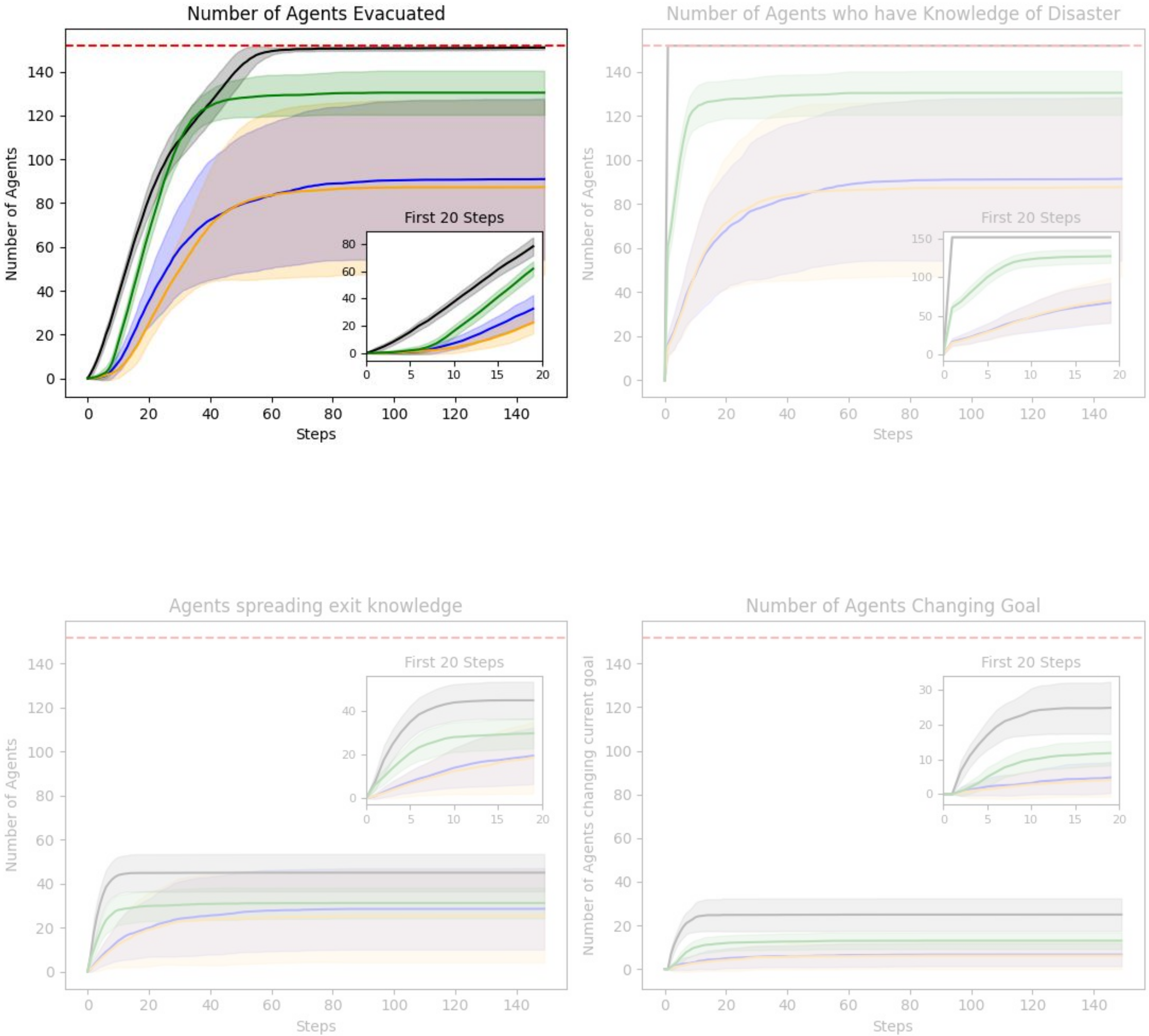




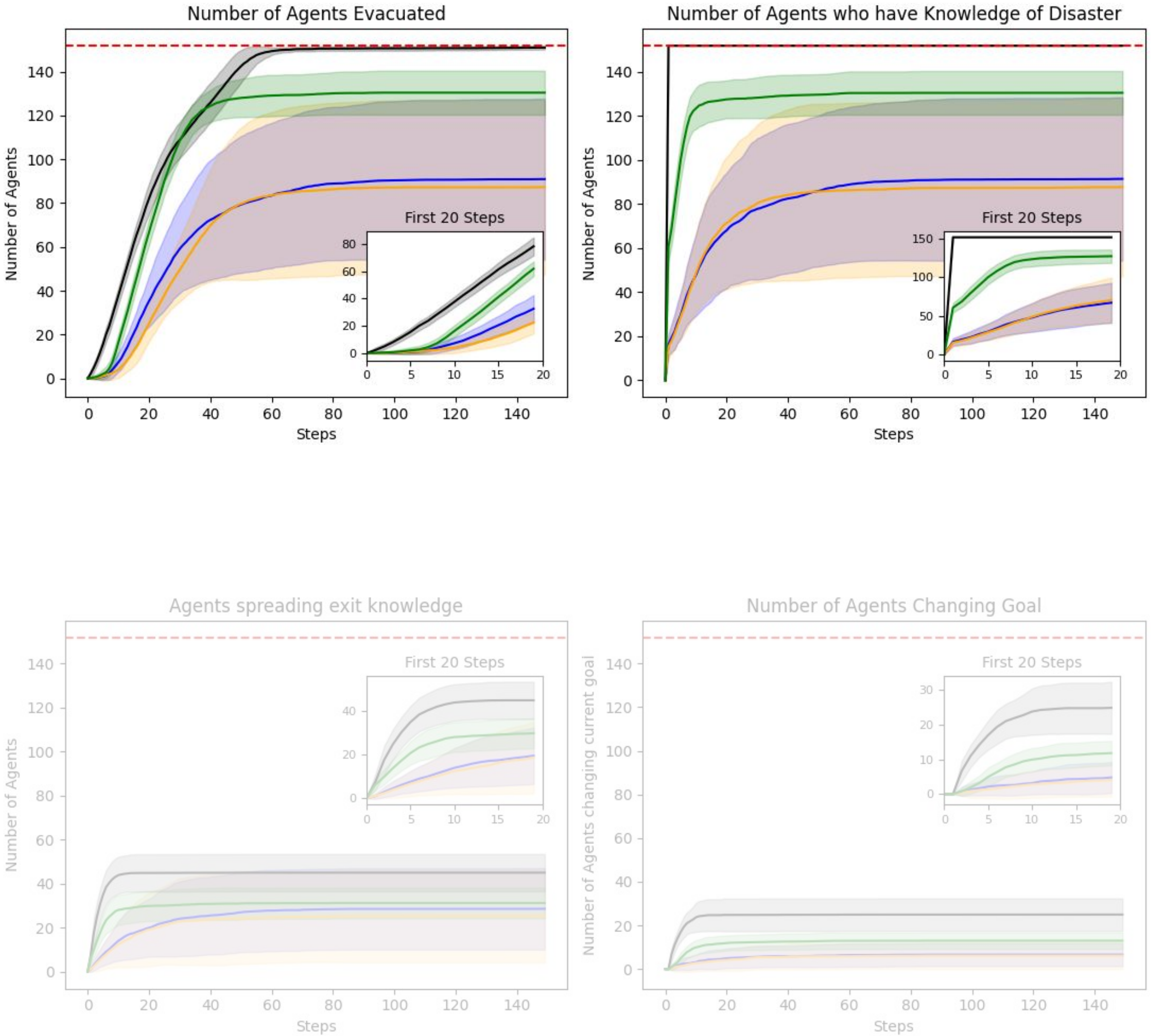



Environmental Familiarity
Number of Agents Evacuated
Knowledge of Disaster
Agents spreading exit knowledge
Changing Goal
Number of Agents who know about an exit
Number of Agents
Steps
Environmental Familiarity
No Prior Exit Knowledge
Total Agents

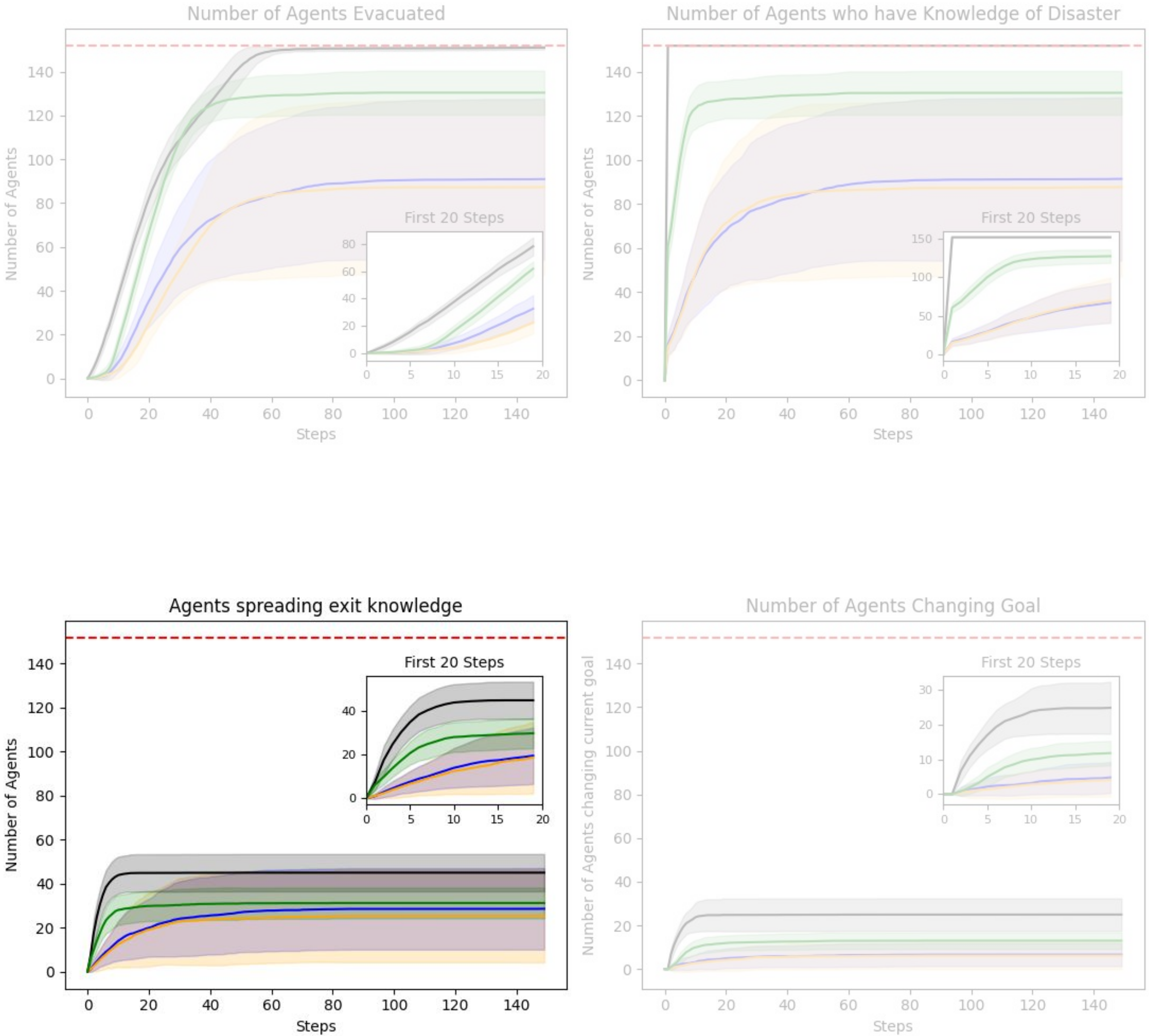
Intervention Strategies



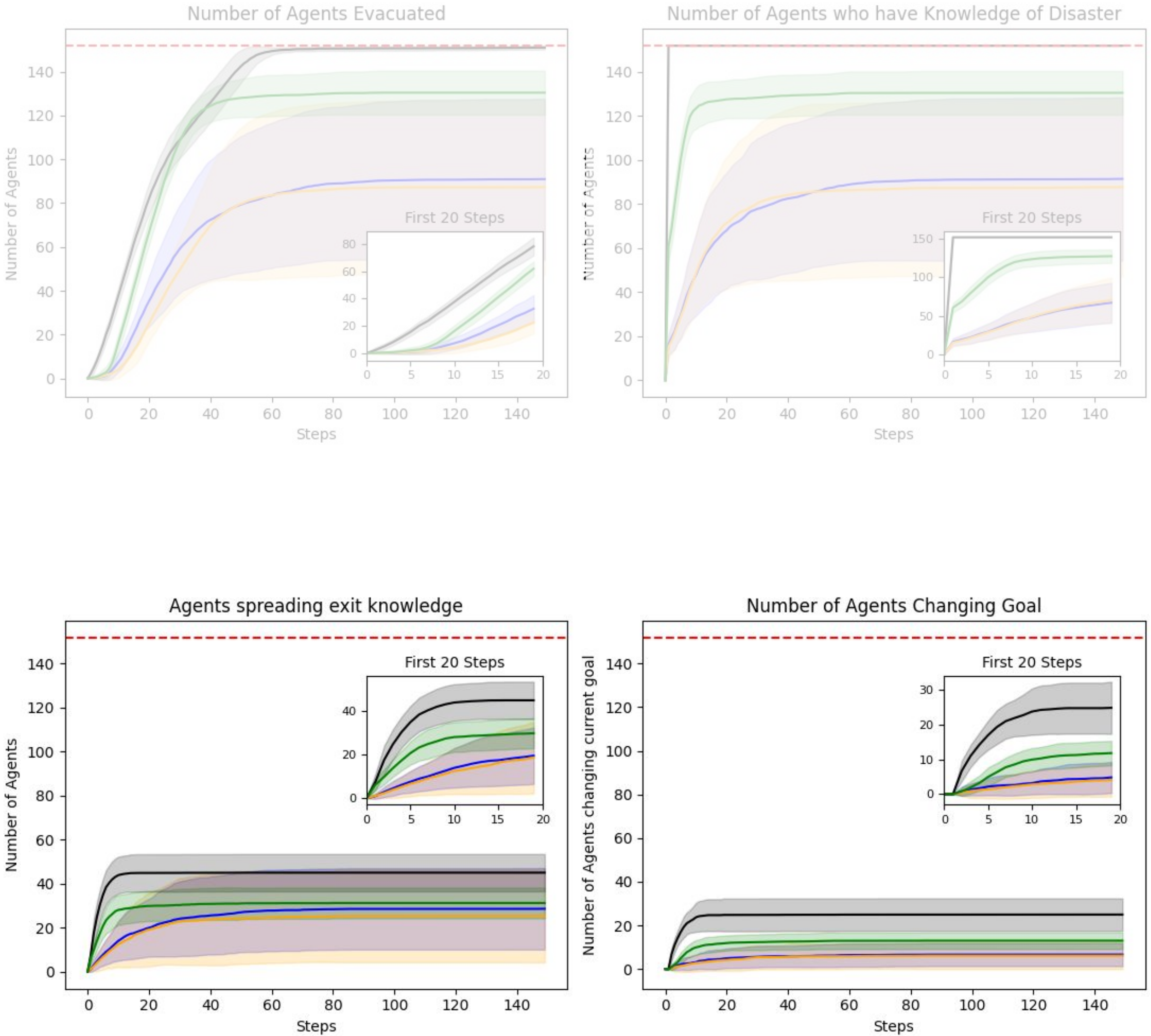
Intervention Strategies

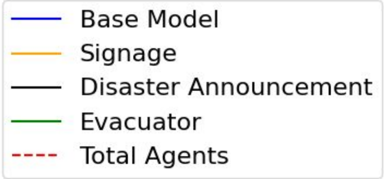


Intervention Strategies

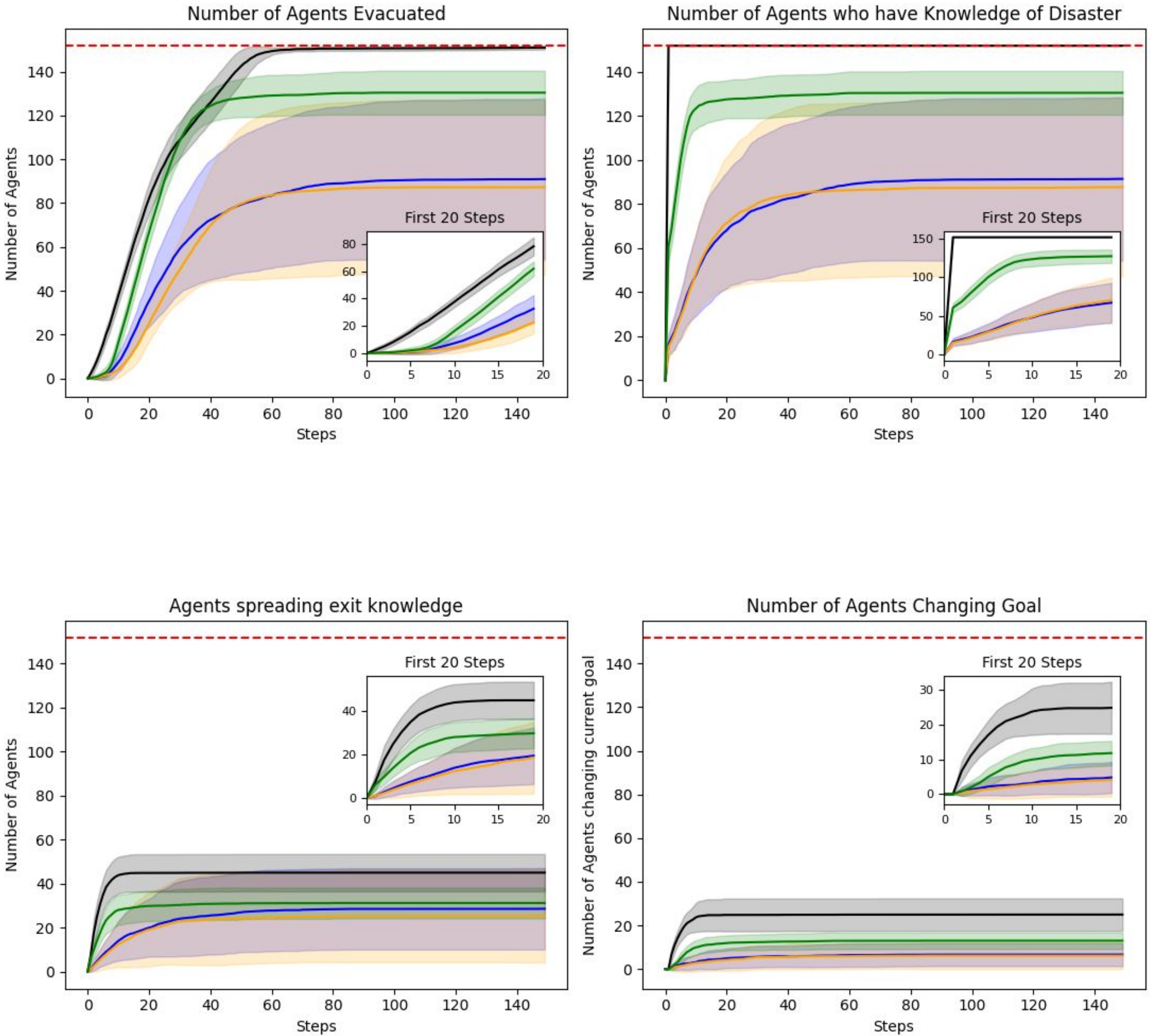


Intervention Strategies



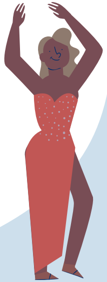


Intervention Strategies



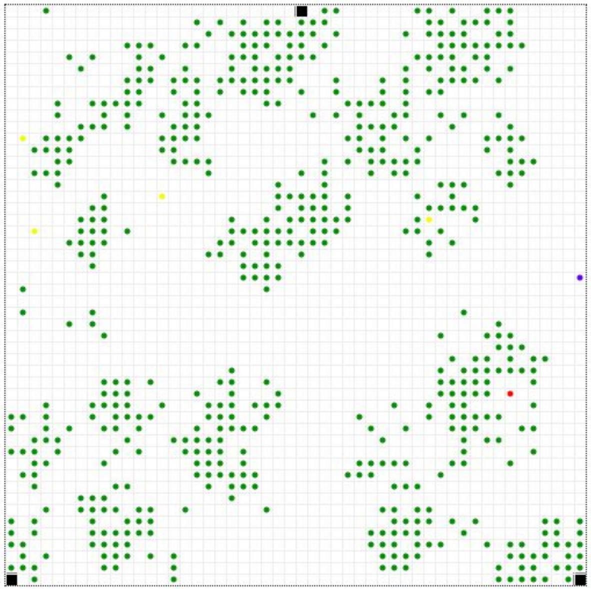
04

Conclusion and Discussion



Key findings

- Cluster formation as emergent behaviour
- Disaster knowledge > environmental knowledge
- Outlier agents save lives



Conclusions

- Environmental familiarity leads to faster, but incomplete evacuation compared to a model without prior knowledge

- Disaster announcement and evacuator presence leads to faster evacuation but not signage

Discussion

- Signage implementation
- Environmental knowledge through information spreading
  - Future: Experiments with radius size variations.
- Social force extension (e.g. groups)
- Bigger grid and obstacles (increased importance of environmental knowledge?)
- Combination of interventions
- Global sensitivity analysis


Thank you

References

Bonabeau, Eric (2002). “Agent-based modeling: Methods and techniques for simulating human systems”. In: Proceedings of the national academy of sciences 99.suppl 3, pp. 7280-72

Freepik. (n.d.). A large crowd of people inside a mall. Freepik. https://www.freepik.com/premium-photo/large-crowd-people-inside-mall_2386643861.htm

Helbing, Dirk and Peter Molnar (1995). “Social force model for pedestrian dynamics”. In: Physical review E 51.5, p. 428

Liu, Qian (2018). “A social force model for the crowd evacuation in a terrorist attack”. In: Physica A: Statistical Mechanics and its Applications 502, pp. 315-330.

Yuan, Weifeng and Kang Hai Tan (2009). “Cellular automata model for simulation of effect of guiders and visibility range”. In: Current Applied Physics 9.5, pp. 1014-1023. issn: 1567-1739. DOI:https://doi.org/10.1016/j.cap.2008.10.007.url:https://www.sciencedirect.com/science/article/pii/S1567173908002733.

Zia, Kashif and Alois Ferscha (2020). “An agent-based model of crowd evacuation: combining individual, social and technological aspects”. In: Proceedings of the 2020 ACM SIGSIM conference on principles of advanced discrete simulation, pp. 129-140

Experiment for base of exit knowledge

Number of known exits	1	2-3	4
People	3	20	5

Parameter settings of the model

```
width = 25
height = 25
N = int(0.25 * width * height)
fire_radius = 10
social_radius = 2
p_spreading = 0.2
p_spreading_environment = 0.3
p_env_knowledge_params = [3/25, 20/25] # threshold 1 (no knowledge), threshold 2
(one door known)
evacuator_radius = social_radius * 4
fire_avoidance_radius = 1
gumbel_params = [1,0.5,1,0.5] # mean and std of goal_attraction + mean and std of
social_repulsion
print(width // 10)
print(width // 13)
exits = [ {"location": (width // 2, height - 1), "radius": 5},
          {"location": (0, 0), "radius": 3},
          {"location": (width - 1, 0), "radius": 3}]
grid = CanvasGrid(portrayal, width, height)
```

Local sensitivity analysis