NDSEG

NATIONAL DEFENSE SCIENCE AND ENGINEERING GRADUATE FELLOWSHIP PROGRAM

Mechanical Engineering

Adaptive animal-robot arena for ethologically relevant behavioral studies

Results from a novel behavioral task combining competitive interaction and complex environments

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INTRODUCTION

Our lab developed a fully automated system with reconfigurable obstacles, continuous tracking, and an autonomous robot agent to investigate ethologically relevant behaviors in more naturalistic scenarios. Our lab uses this platform to better understand cognitive processes such as planning and decision-making. Planning is deliberative, flexible decision-making—the ability to imagine and evaluate future actions before selecting one. This capability allows prey to envision possible routes and select the most likely to ensure survival. We seek to understand why planning evolved and what conditions encourage deliberate, flexible, goal-seeking behavior as opposed to habitual, repetitive routines. We designed a novel naturalistic predator-prey behavioral task called BotEvade[2] to address these questions.

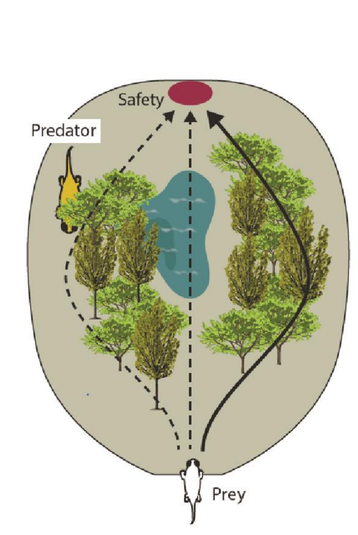

Fig 1.

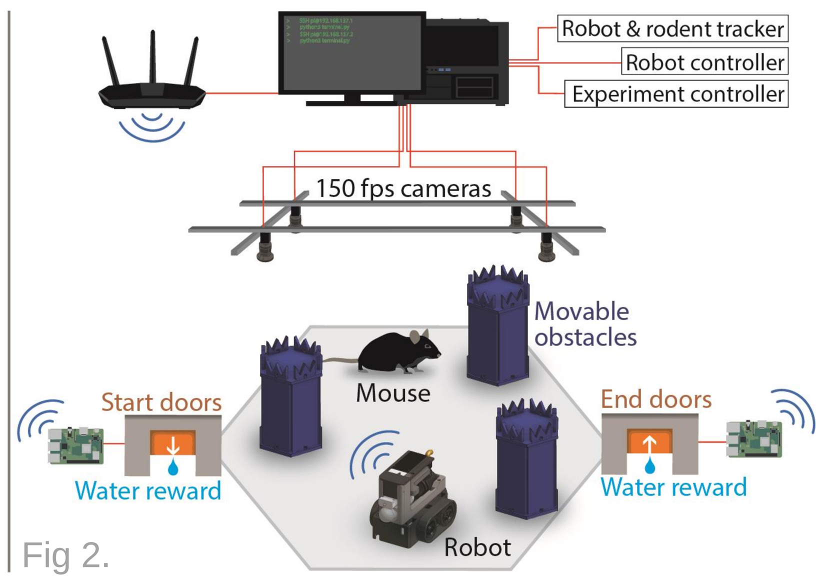

Fig 2.

METHODS

In BotEvade, mice start on one side of a 2.34-meter-wide hexagonal arena and must navigate to the other to reach a water reward while evading an autonomous robot in pursuit.

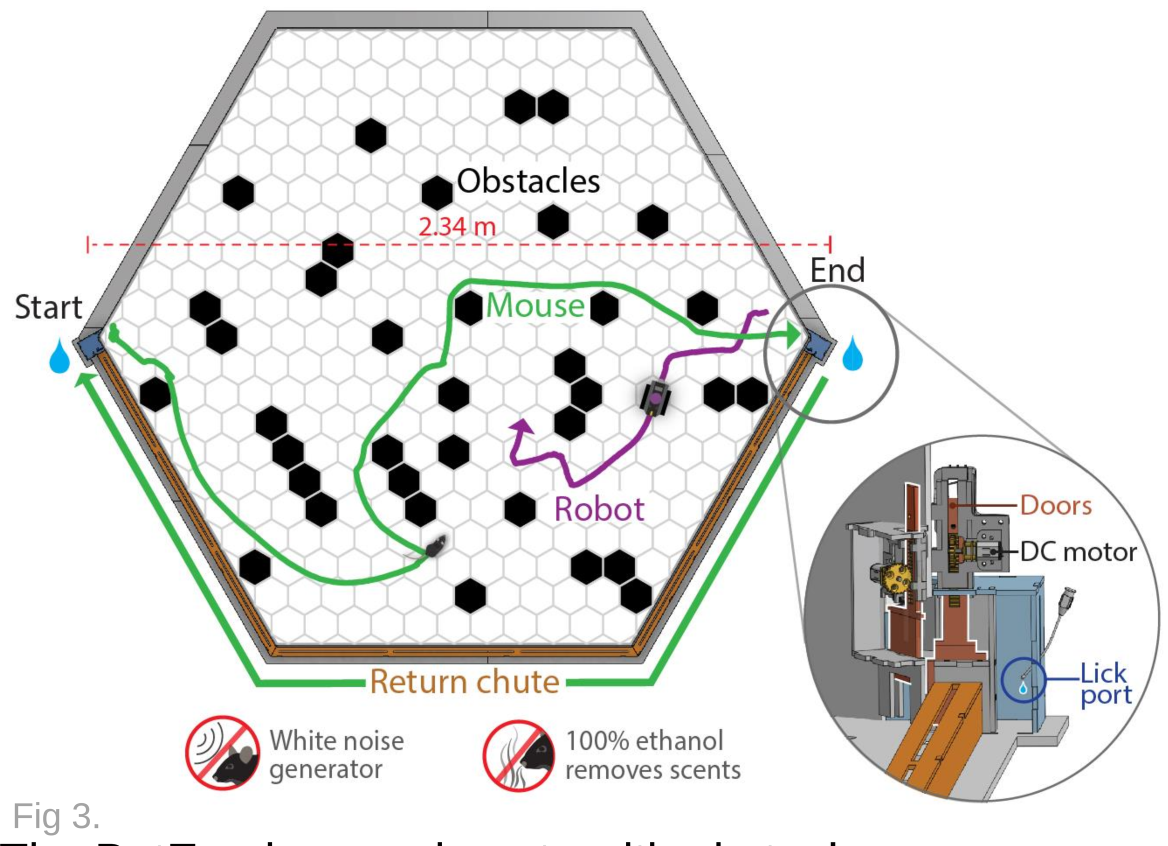

Fig 3.

The BotEvade experiments with obstacles were conducted in a mid-clutter configuration, enhancing the utility for planning[1]. The reconfigurable obstacles allow for various arena layouts, including commonly used laboratory setups for learning and memory.

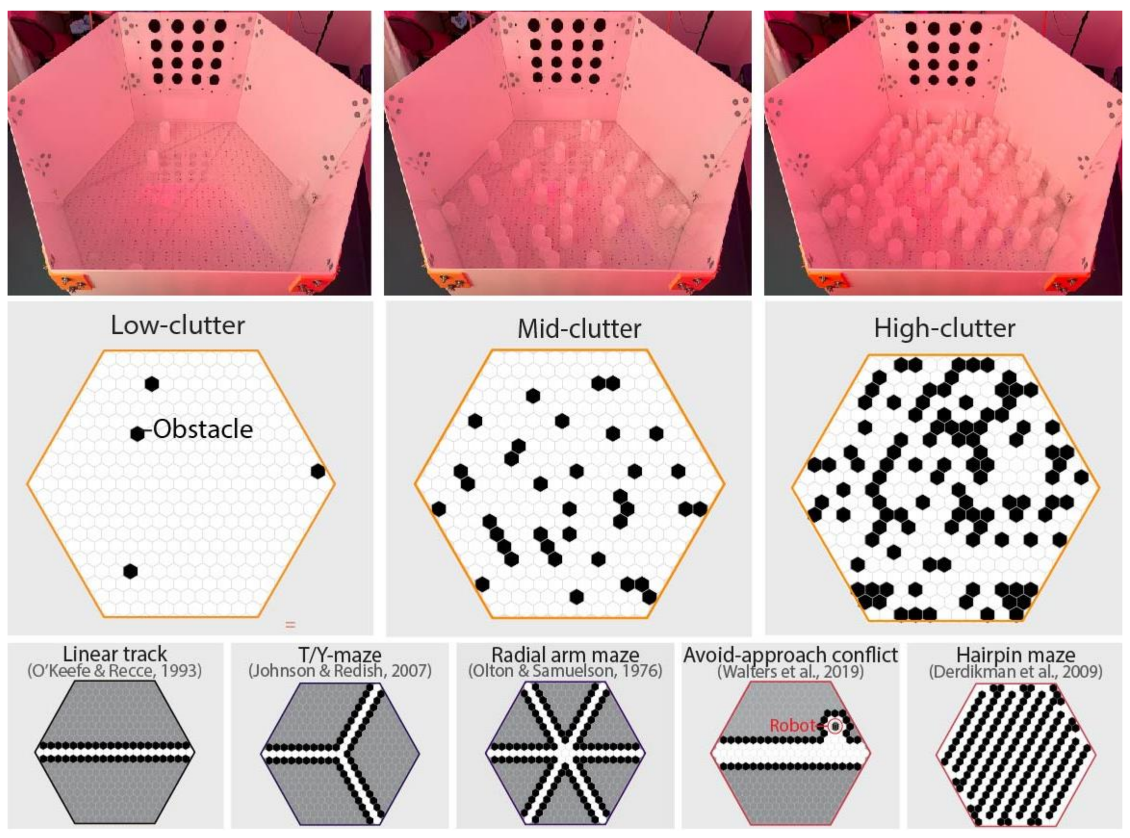

Fig 4.

A custom, fully autonomous robot with closed-loop control, using overhead camera sensors for real-time feedback, was designed and programmed to interact with a mouse.

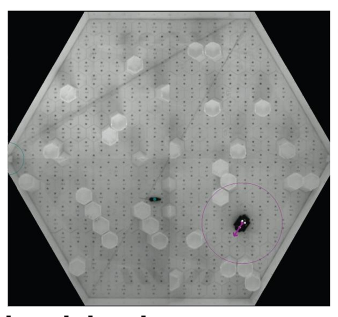

Fig 5.

The robot's movements were synchronized with the mouse's behavior, pursuing the mouse when visible and searching for it when hidden behind obstacles. Additionally, the robot featured a custom aversive stimulus module that delivered a sudden puff when triggered.

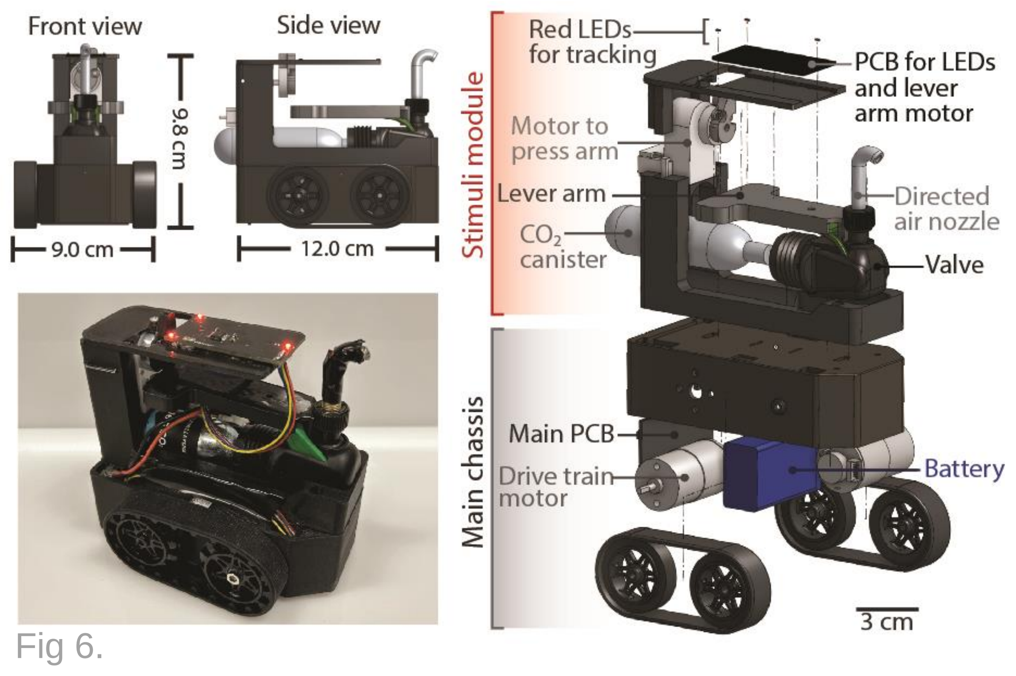

Fig 6.

RESULTS

The experiment consisted of multiple phases over 22 days, with 30-minute sessions involving 8 C57BL/6 mice. Each session contained multiple trials, where the mice traversed from the arena's start to end. Statistics were compared across phases. In a mid-clutter environment, the presence of the robot led to higher path diversity at lower speeds, fewer trials per experiment, and more pausing.

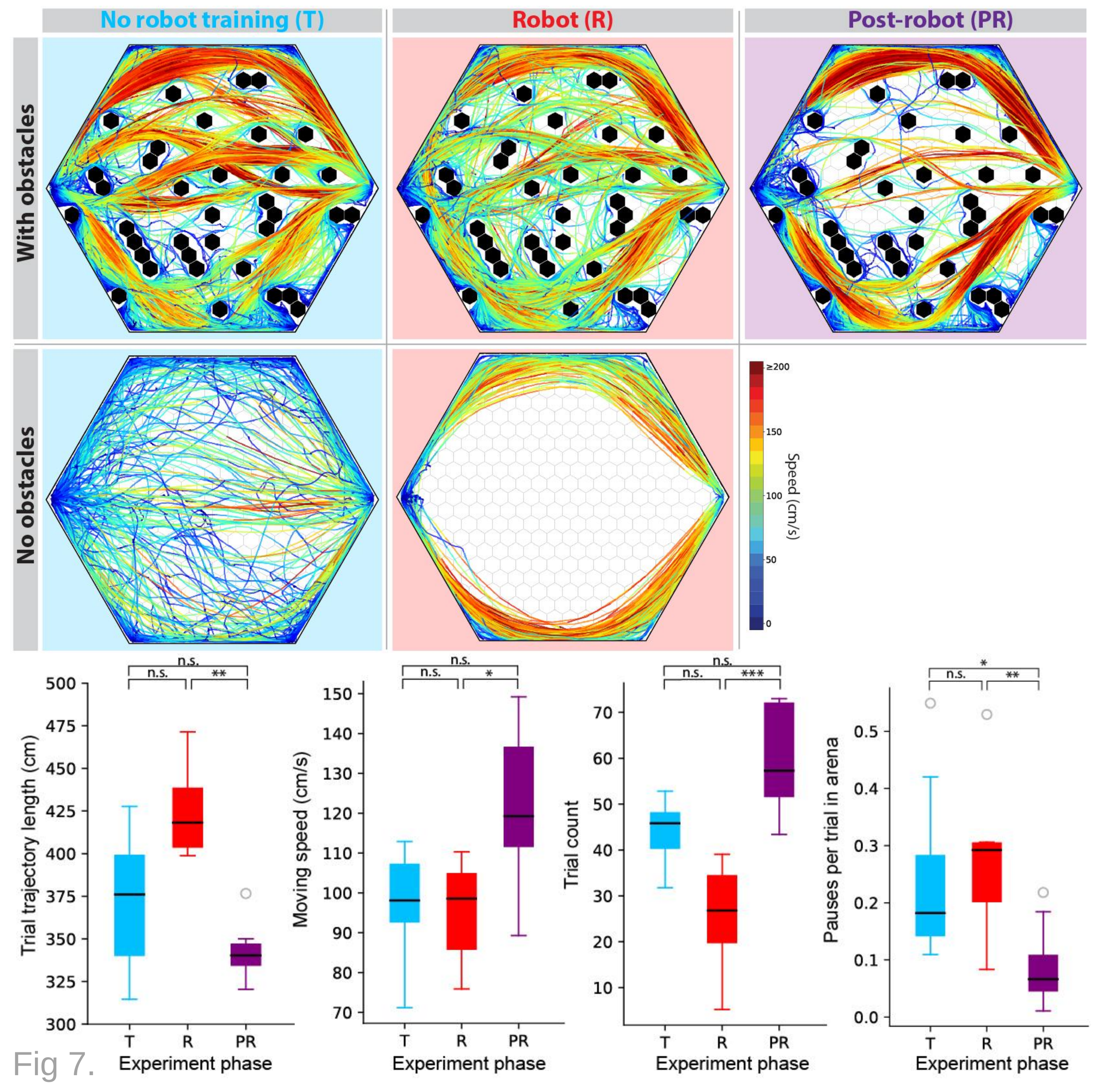

Fig 7.

The presence of the robot in the mid-clutter environment elicits strategic behaviors such as "peeking".[2]

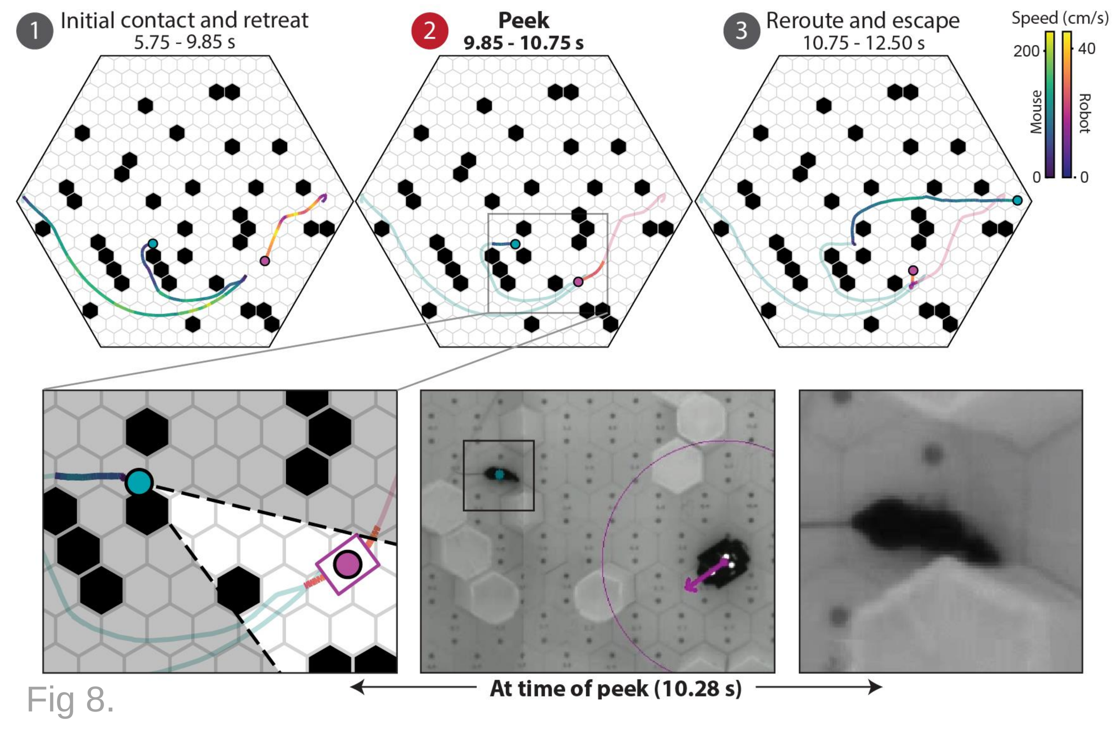

Fig 8.

FUTURE WORK

- Conduct neural recordings during behavioral tasks.
- Conduct more naturalistic behavioral tasks for research domains such as foraging, cooperative avoidance, and hunting.
- Exploring how the robot's predation strategy impacts the effectiveness of planning and the animal's decision-making through the following:
  - Further development of the predator robot's predation strategy by exploring various decision-making algorithms.
  - Investigate and predict interactions between the mouse and the autonomous robot as the robot's strategy is manipulated.

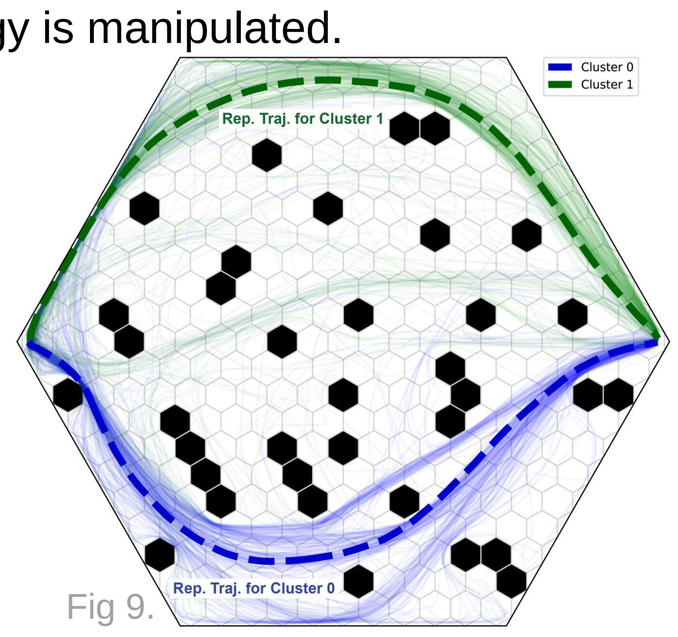

Fig 9.

BENEFITS TO DOD

- A platform to study cognitive processes such as decision-making and planning with environmental variability and interactivity absent from most behavioral paradigms. This research can inform strategies to enhance both human and machine planning capabilities.
- The BotEvade study provides data on how animals (mice) make decisions when faced with a threat and a goal.
- A platform to predict and study interactions between animals and robots.
- A platform to investigate decision-making algorithms for autonomous robots with multi-intentions.
- Development of a predator agent that operates autonomously in complex and dynamically changing states.

CONCLUSION

Our lab developed a fully automated robot-rodent interaction arena with adjustable spatial complexity to study ethologically relevant behaviors in repeatable, more naturalistic environments. Using this platform, we plan to study cognitive processes such as planning and decision-making. The BotEvade[2] task revealed that the presence of the robot predator influenced mouse behaviors, providing insights into the conditions that promote rich emergent behaviors indicative of planning.

Acknowledgements

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**Figures 2,3,4,7, and 8 are adapted from Reference 2*

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