An ACT-R model of collaborative skill acquisition for Coop Space Fortress

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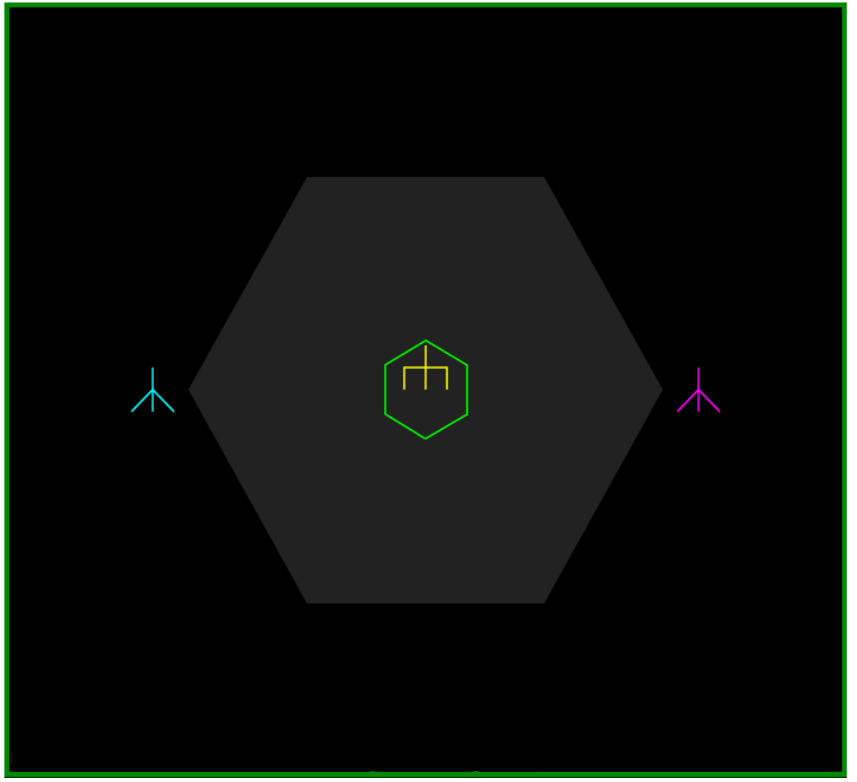
Coop Space Fortress

Game description

- **Goal**: kill fortress located at center of screen
- **Roles**: one player baits the fortress, the other shoots it down; bait should fly slowly
- **Incentivization**: point gains from killing fortress and losses from dying or missing shots



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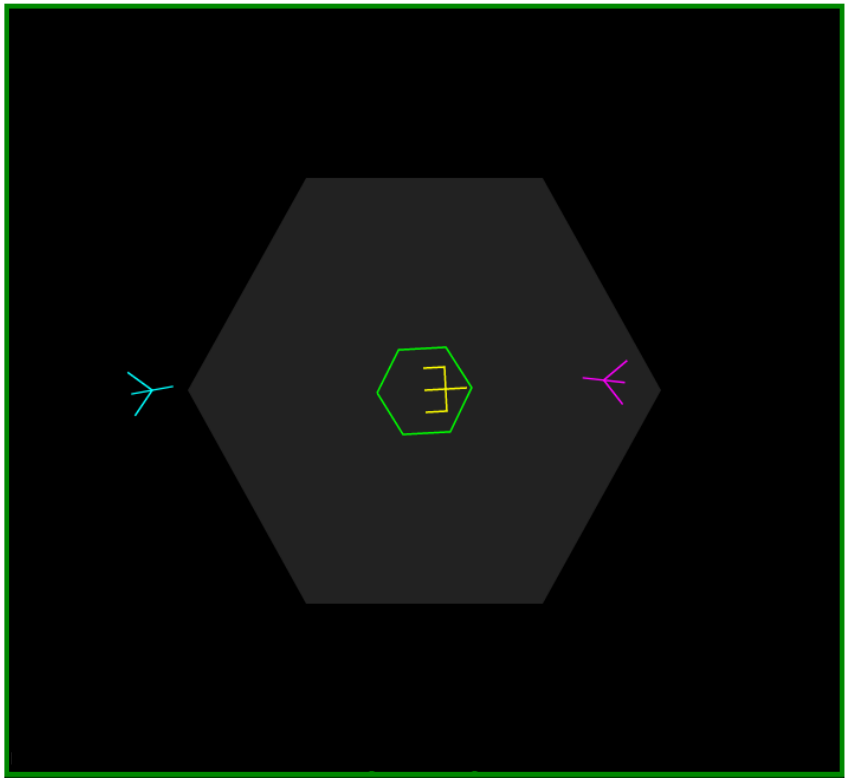

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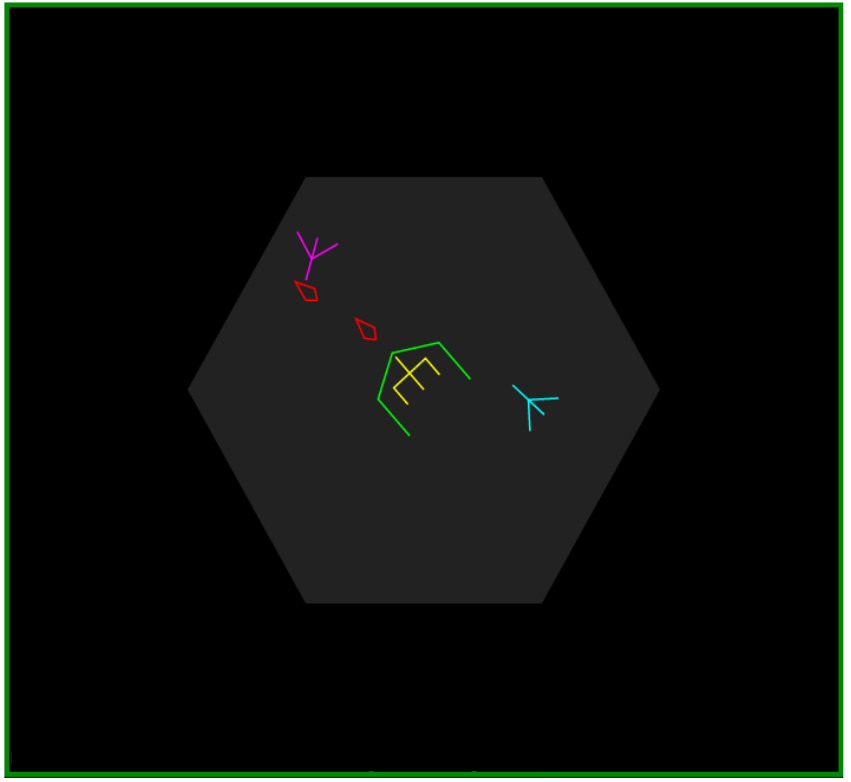

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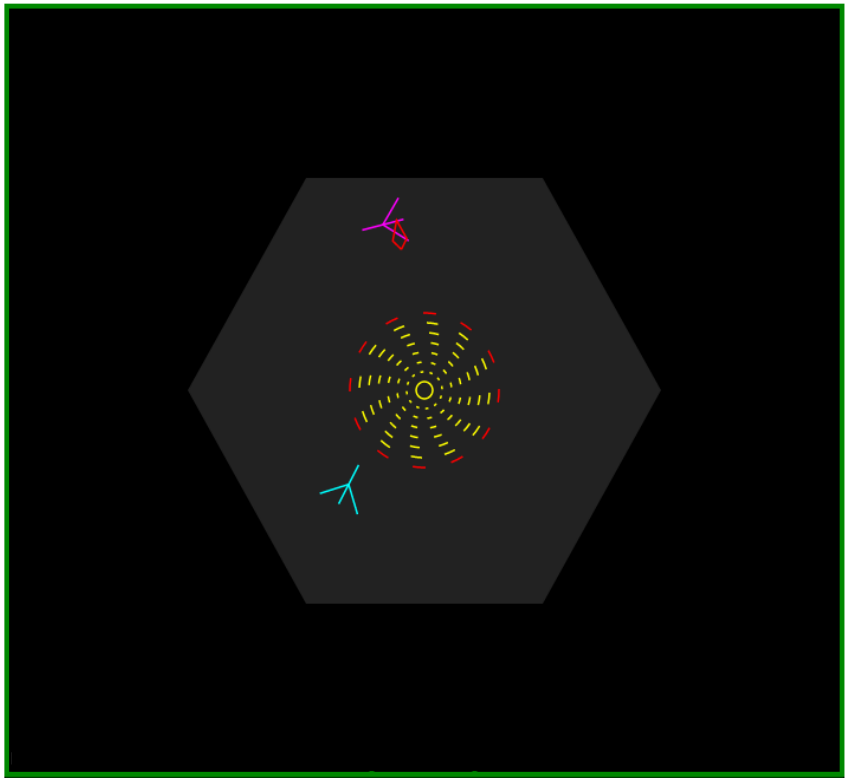


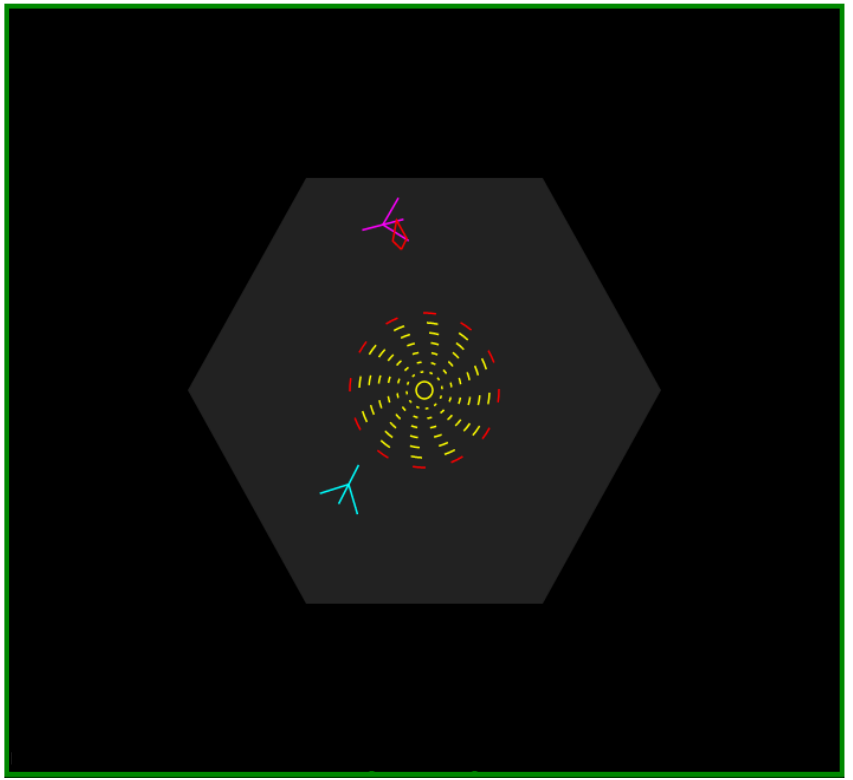
Studies with Coop Space Fortress

Study 1

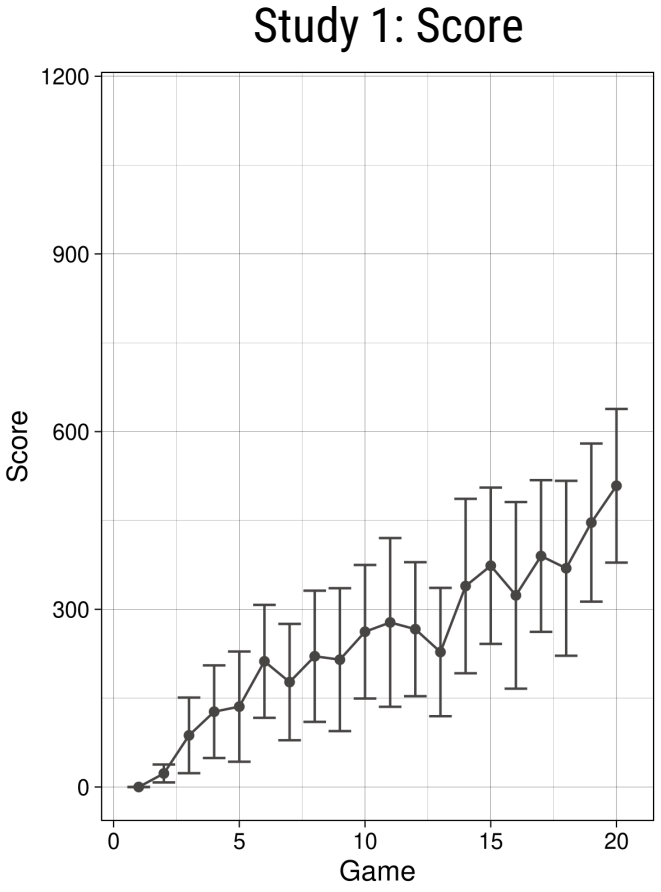
Goal: pilot
Duration: ~ 1 h (20 games x 3 minutes)
Sample: 14 teams

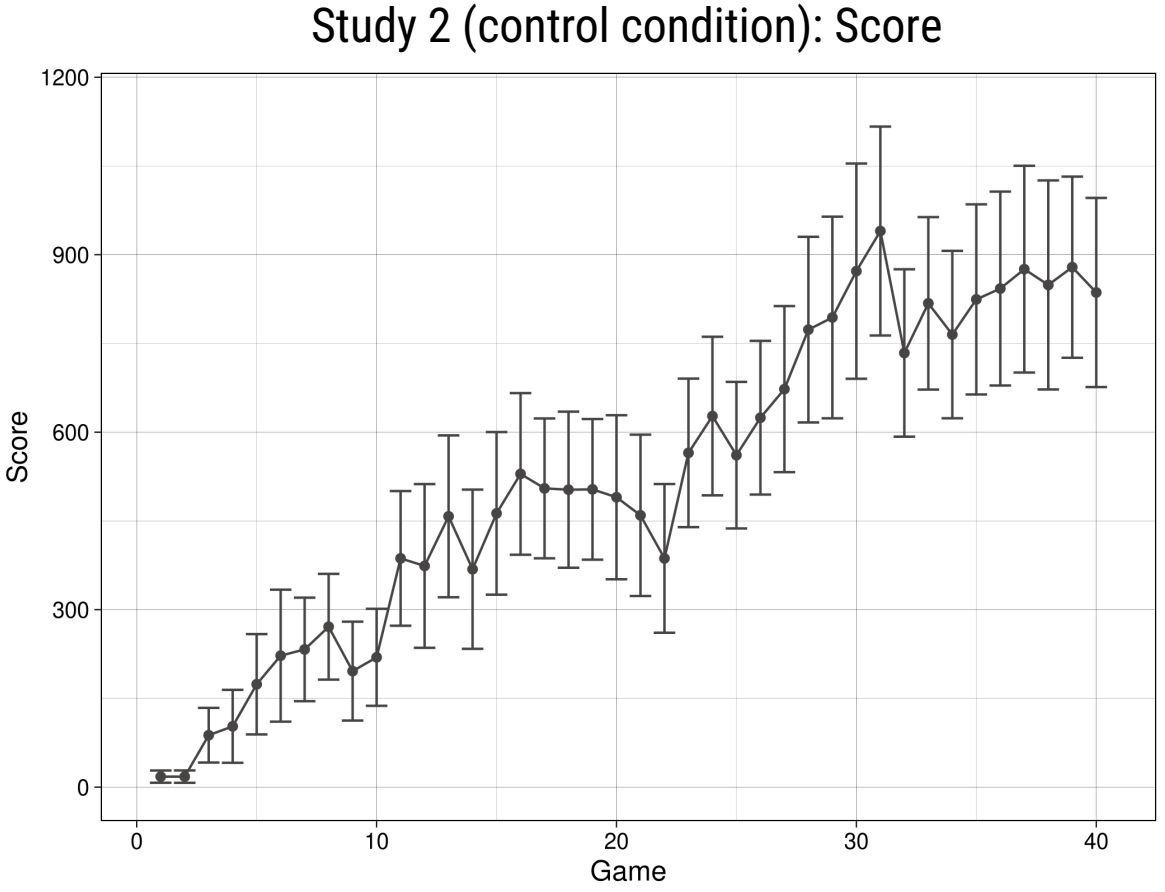
Study 2

Goal: transfer from Space Track
Duration: ~ 2 h (2 sessions)
Sample: 39 teams



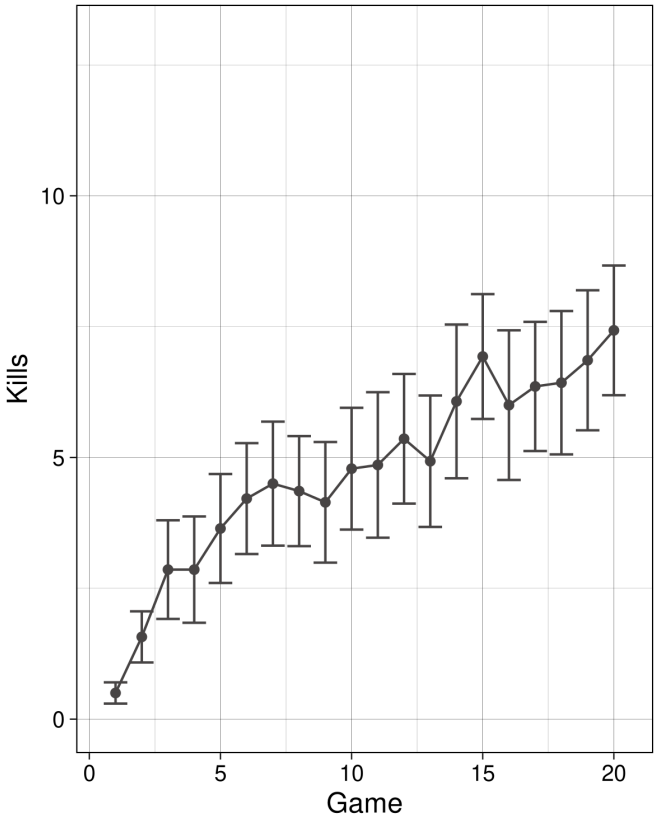
Study Results: Performance



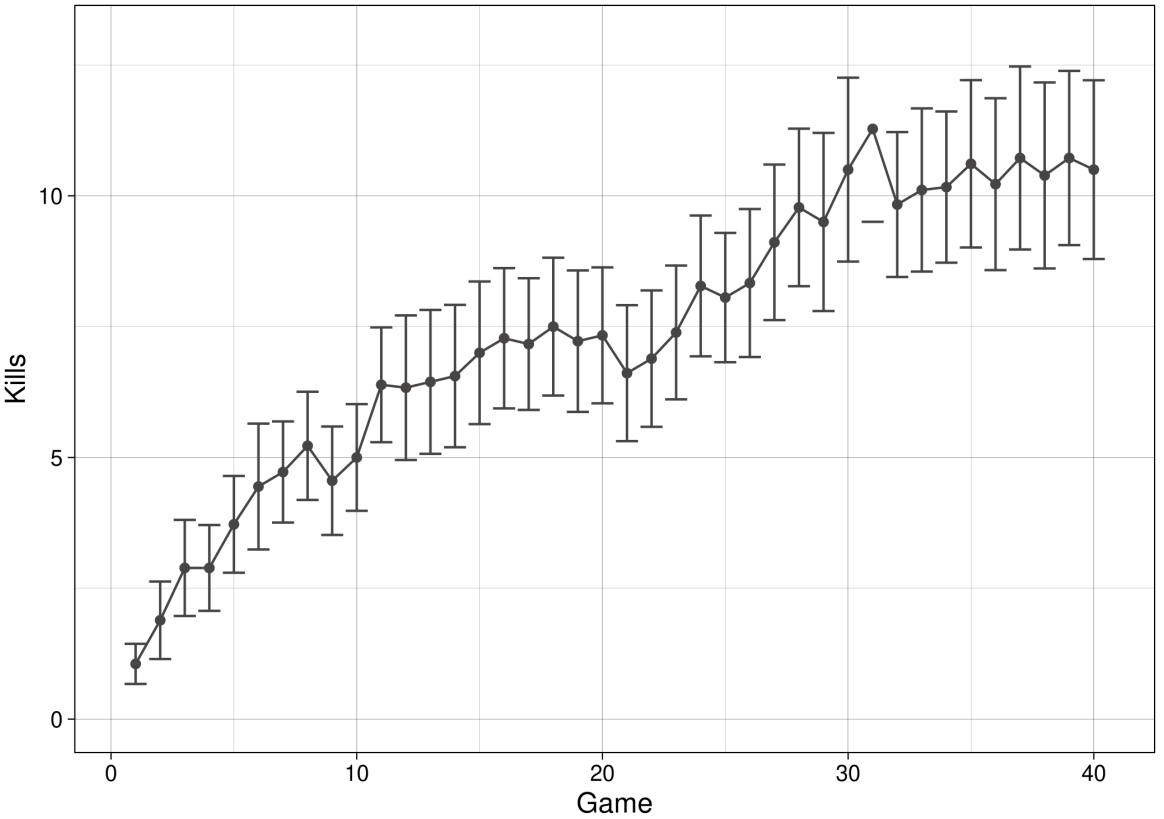


Study Results: Performance

Study 1: Kills

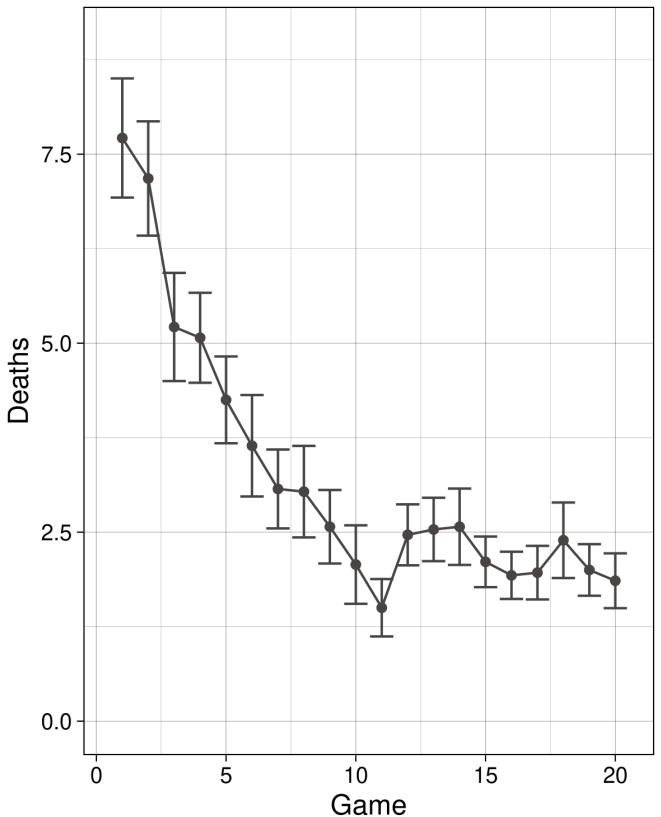


Study 2 (control condition): Kills

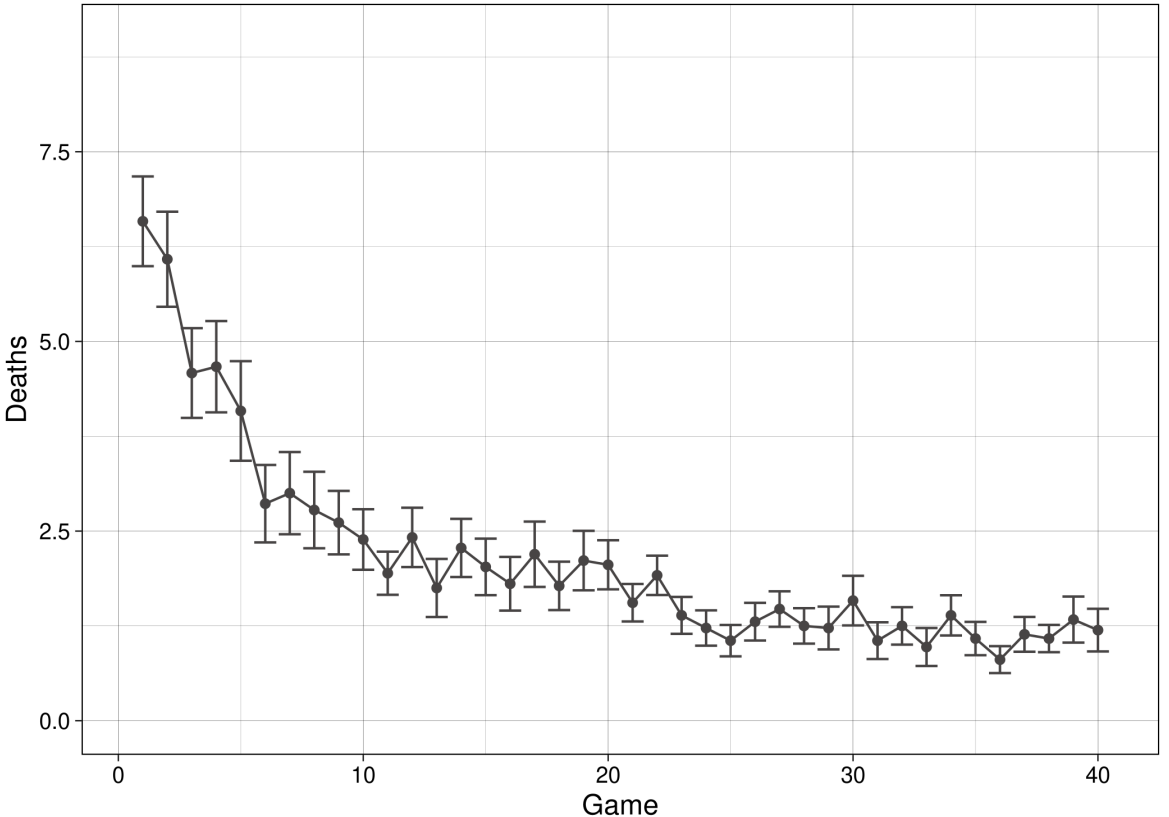


Study Results: Performance

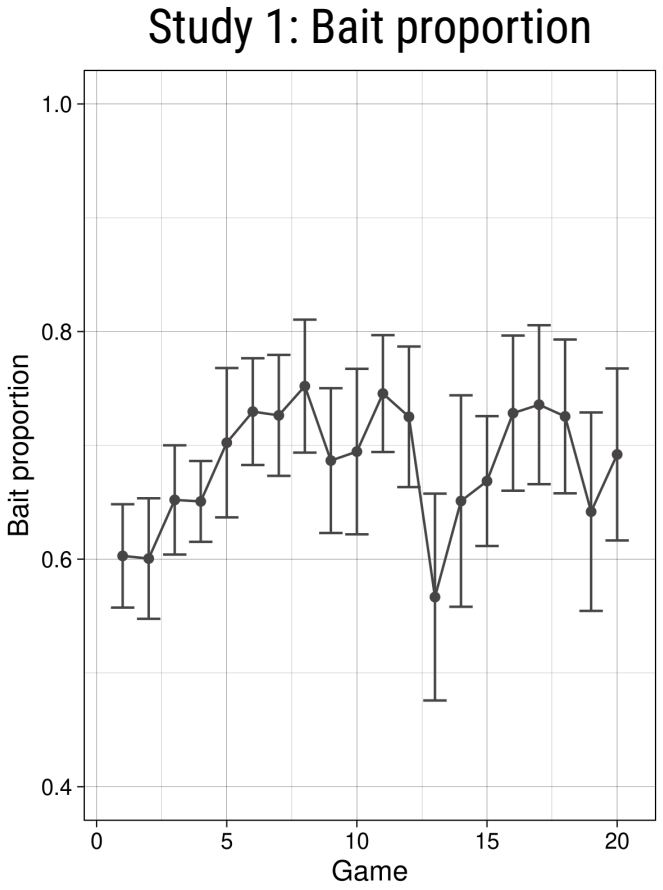
Study 1: Deaths

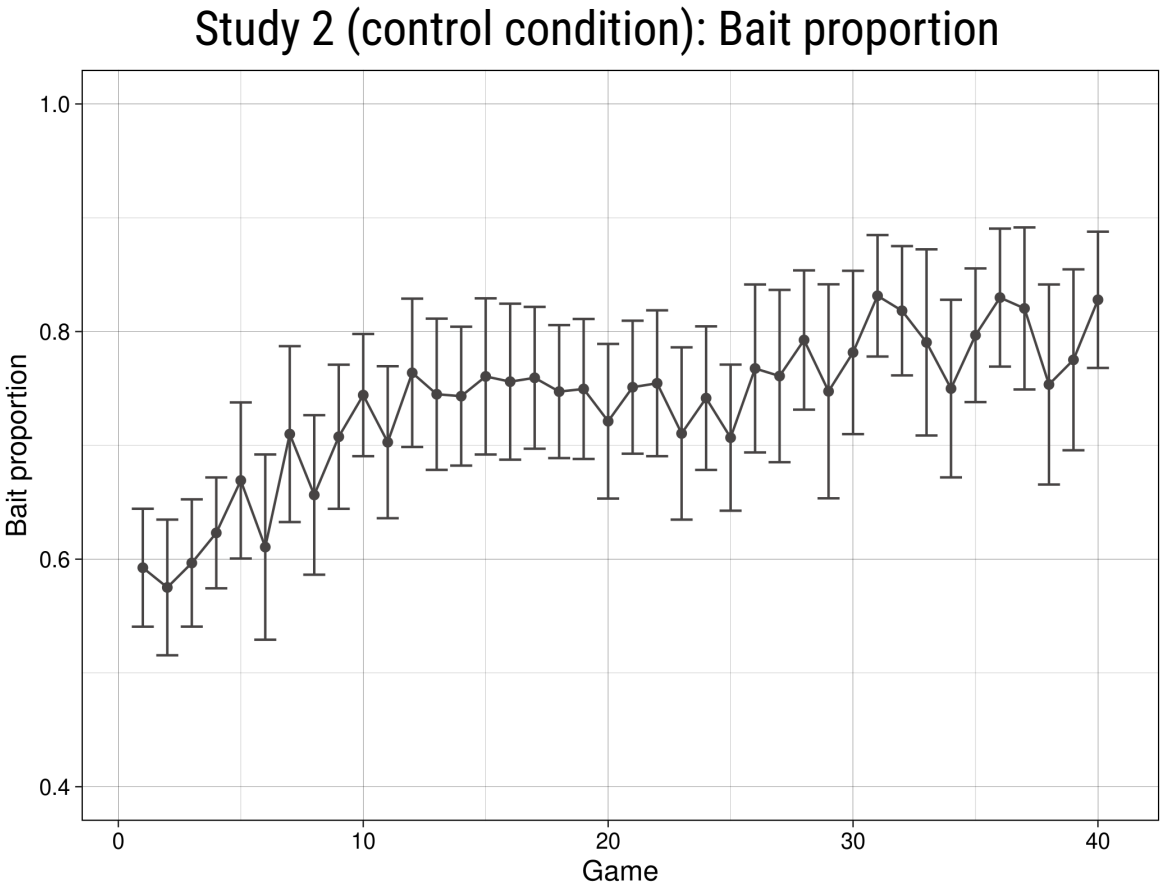


Study 2 (control condition): Deaths

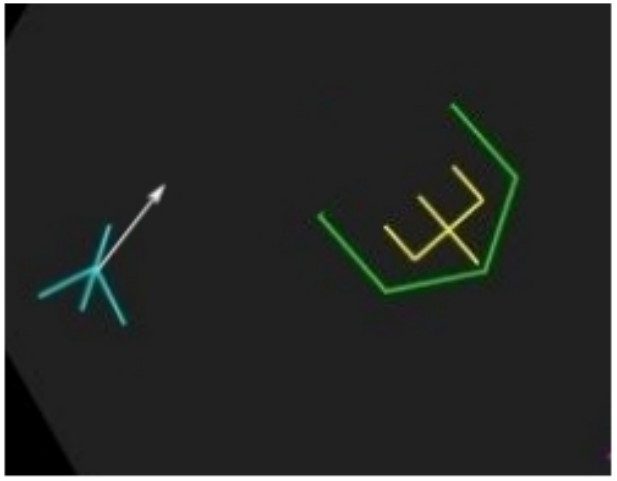


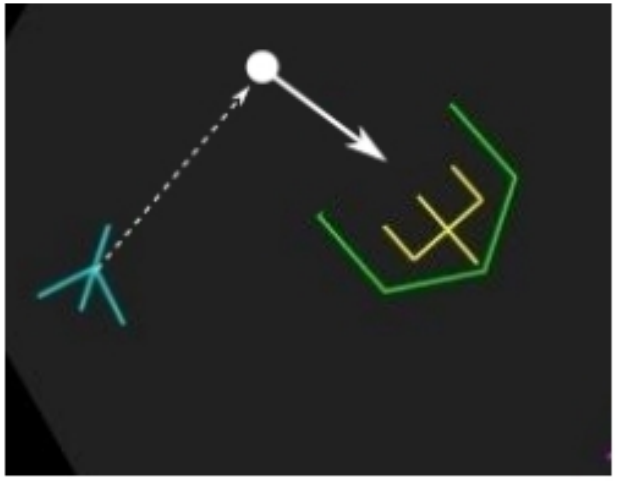
Study Results: Role Consistency

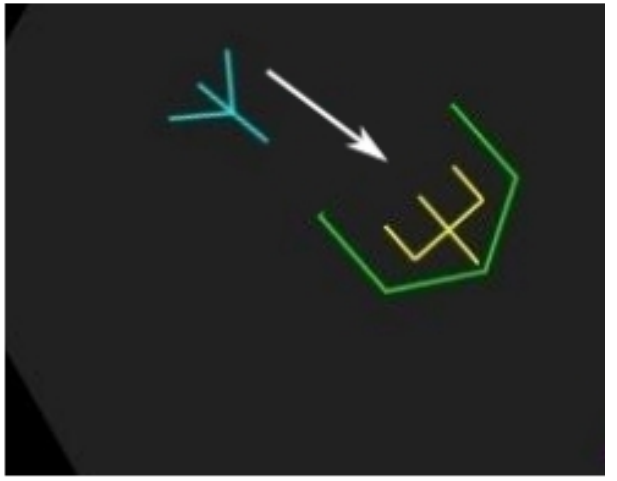




Study Results: Anticipatory Actions







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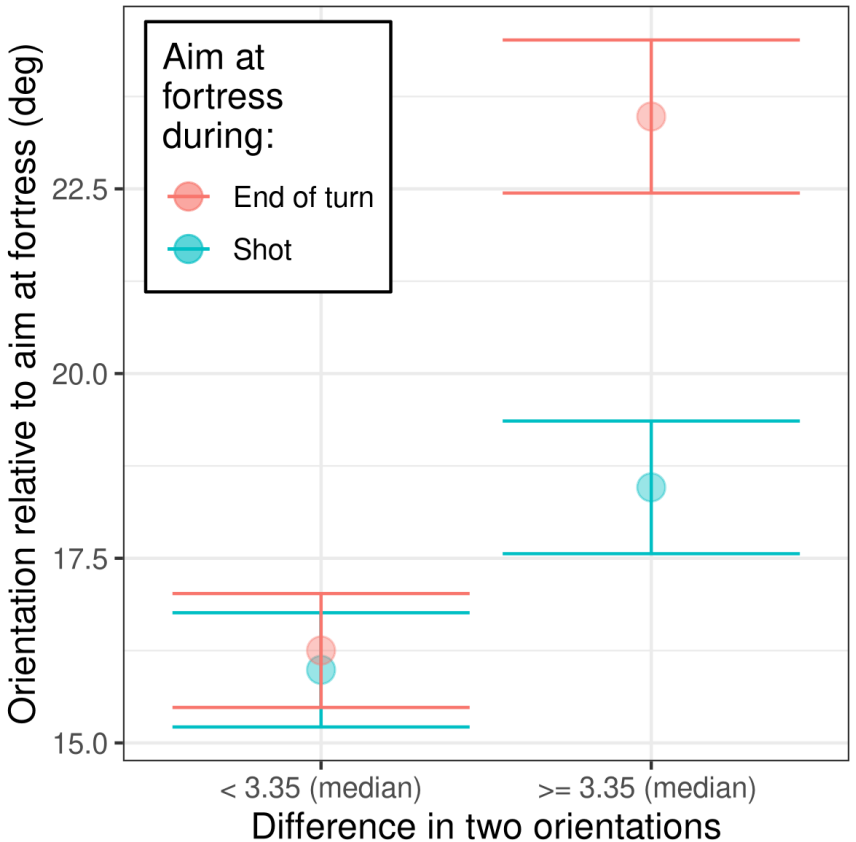

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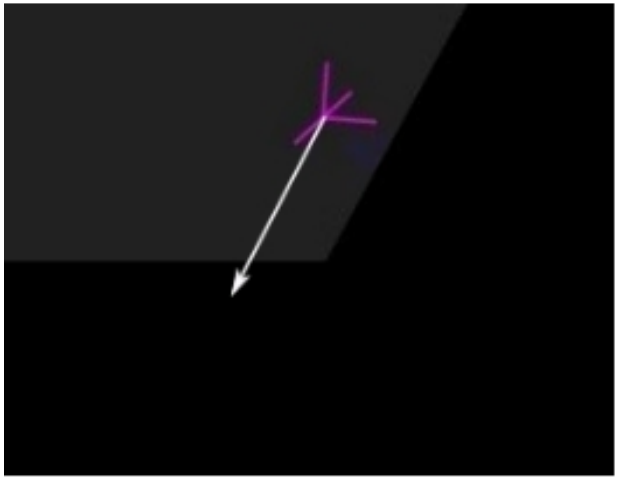

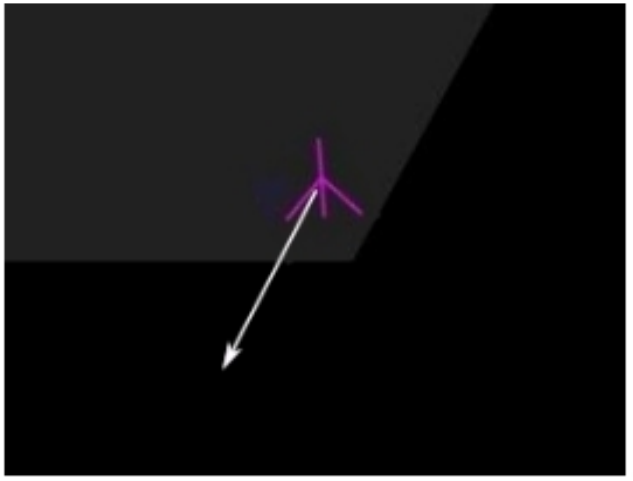

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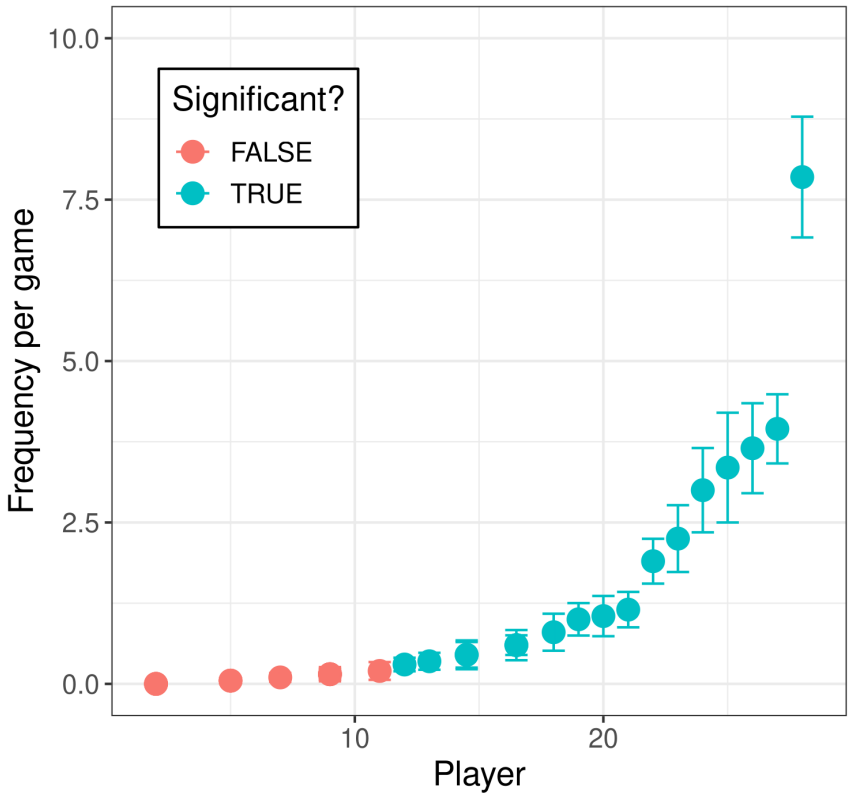


Study Results: Anticipatory Actions

Other anticipatory actions:

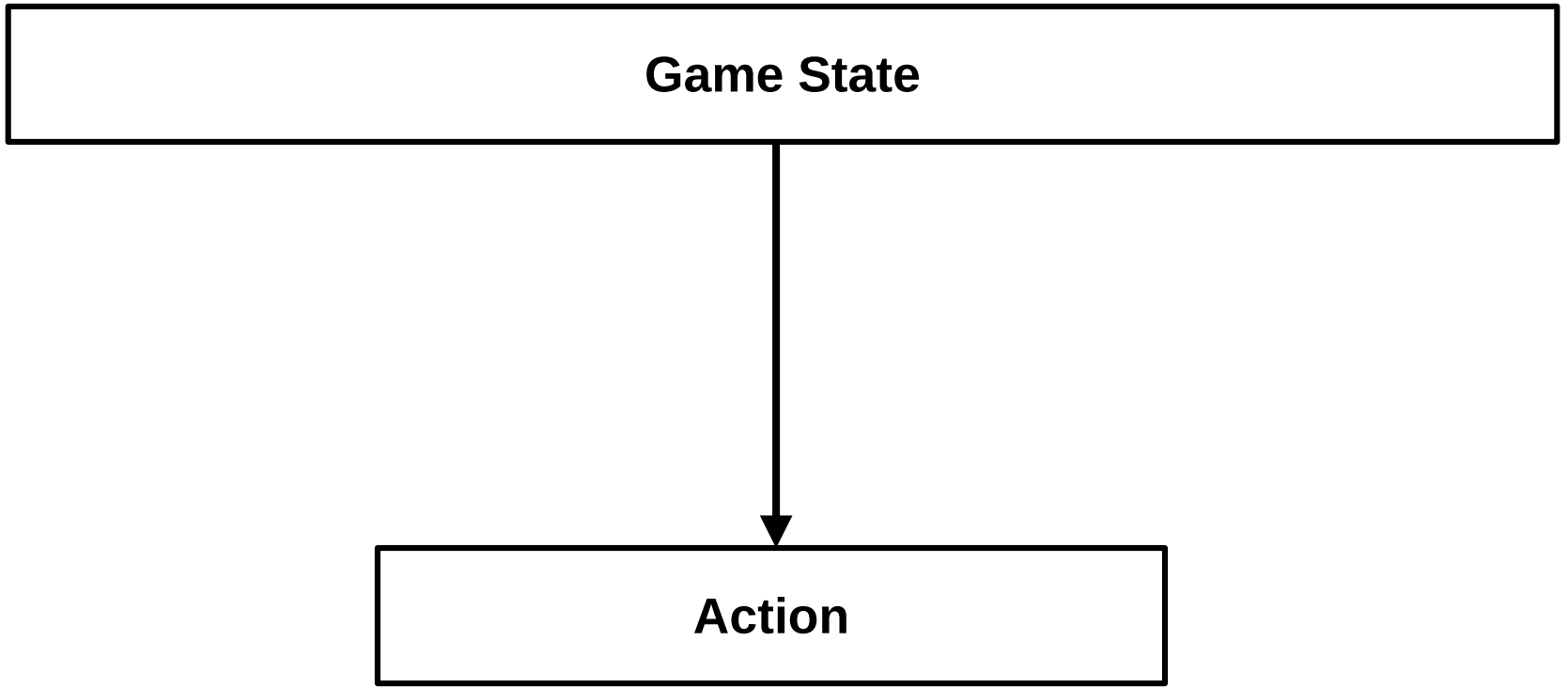
- Preparing to stop when outside
- Avoiding crashing into outer border or fortress
- Bait prepares to slow down before having entered

ACT-R Model: Skill Acquisition Process

1. Cognitive operators
2. Transition from declarative phase to procedural phase
3. Control tuning

Anderson, Betts, Bothell, Hope, & Lebiere (2019)

ACT-R Model: Operators



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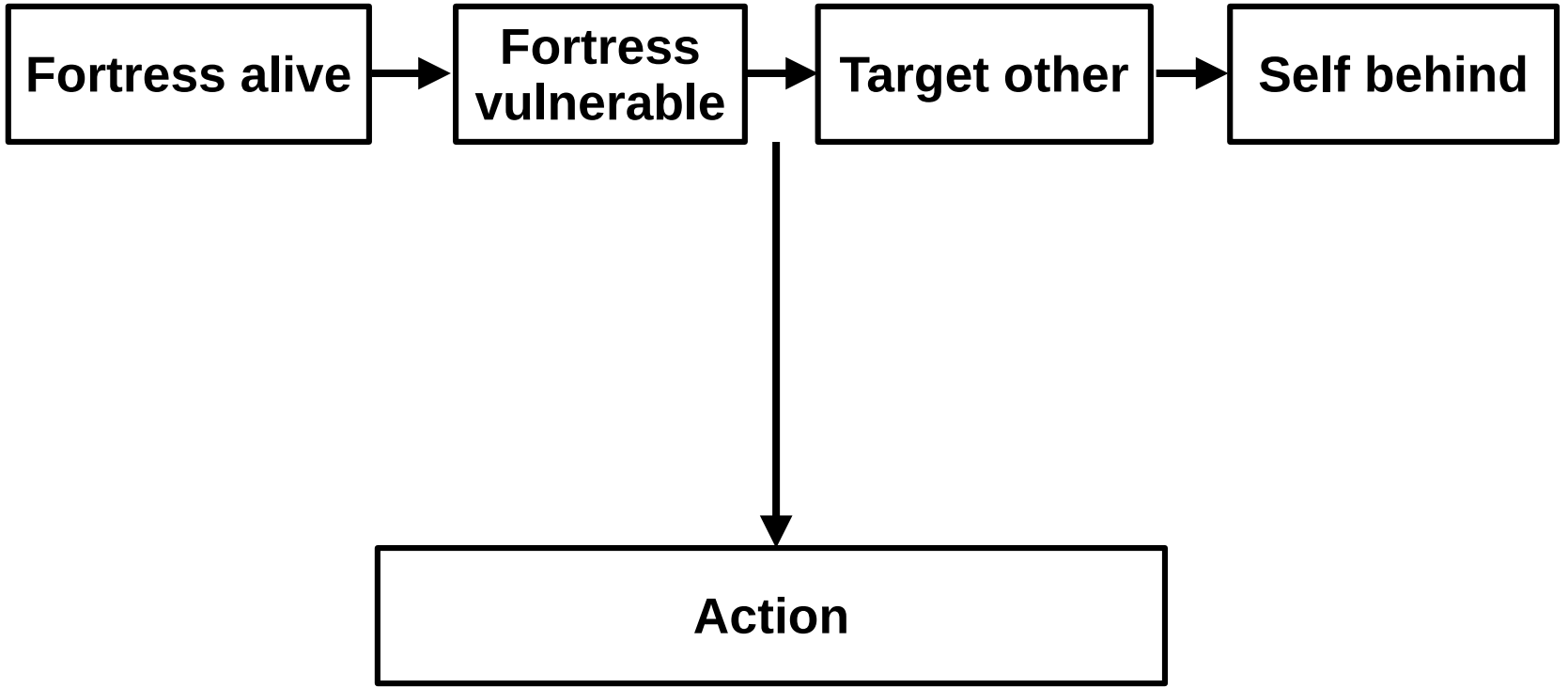

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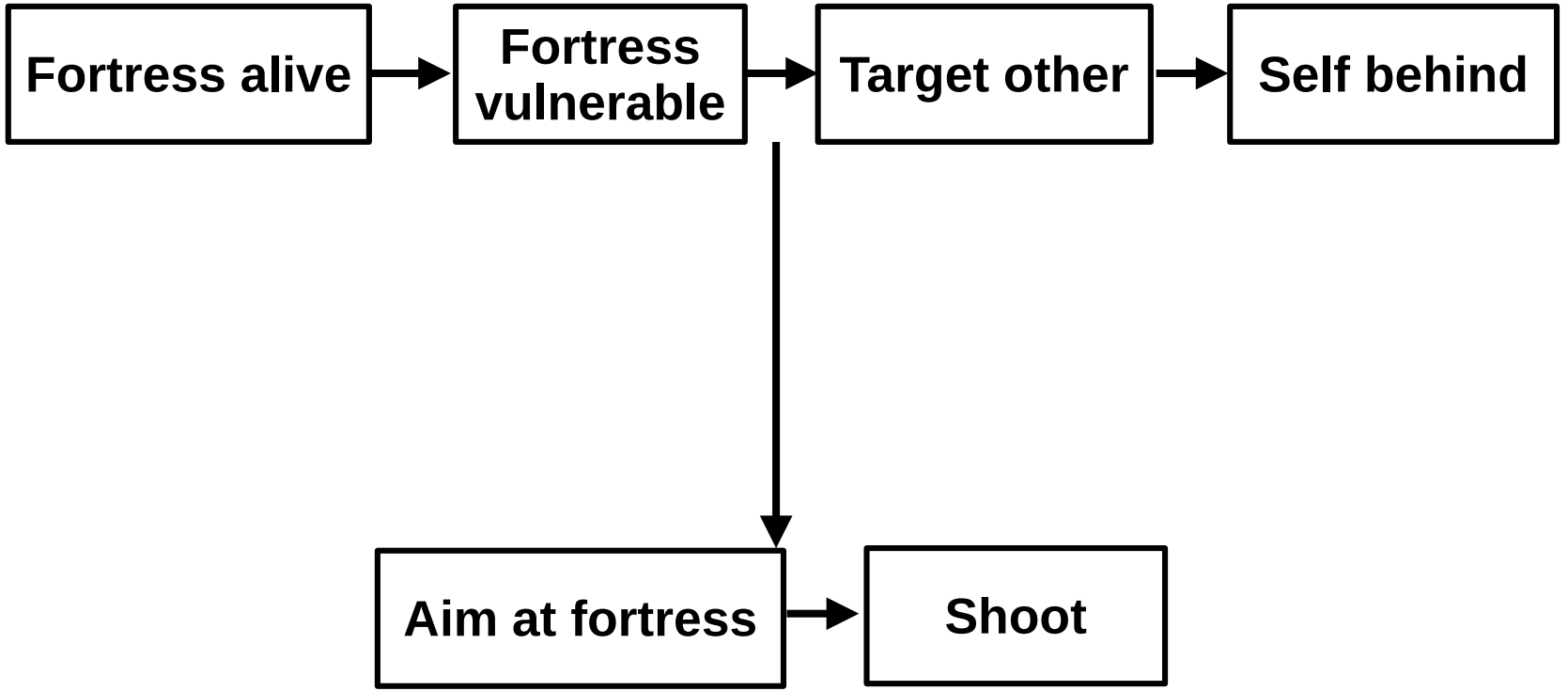

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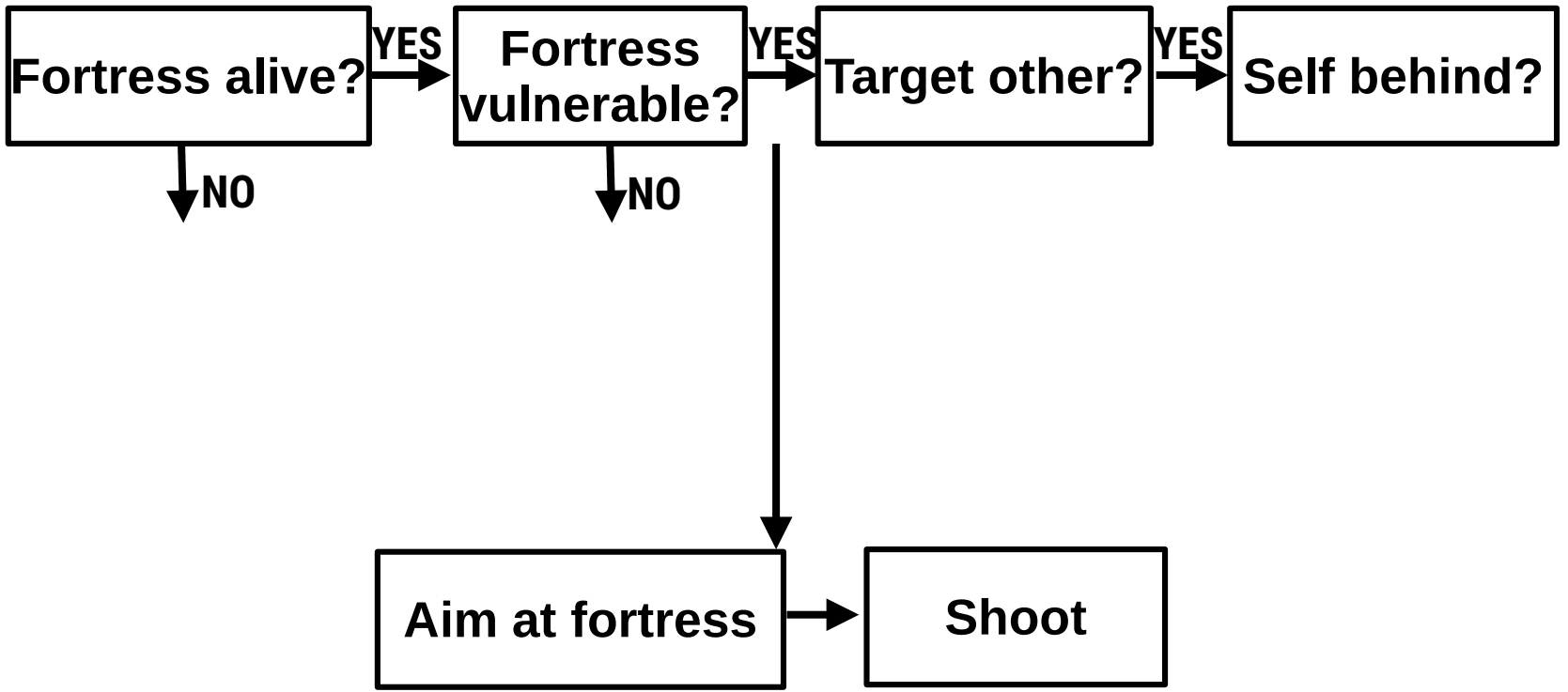
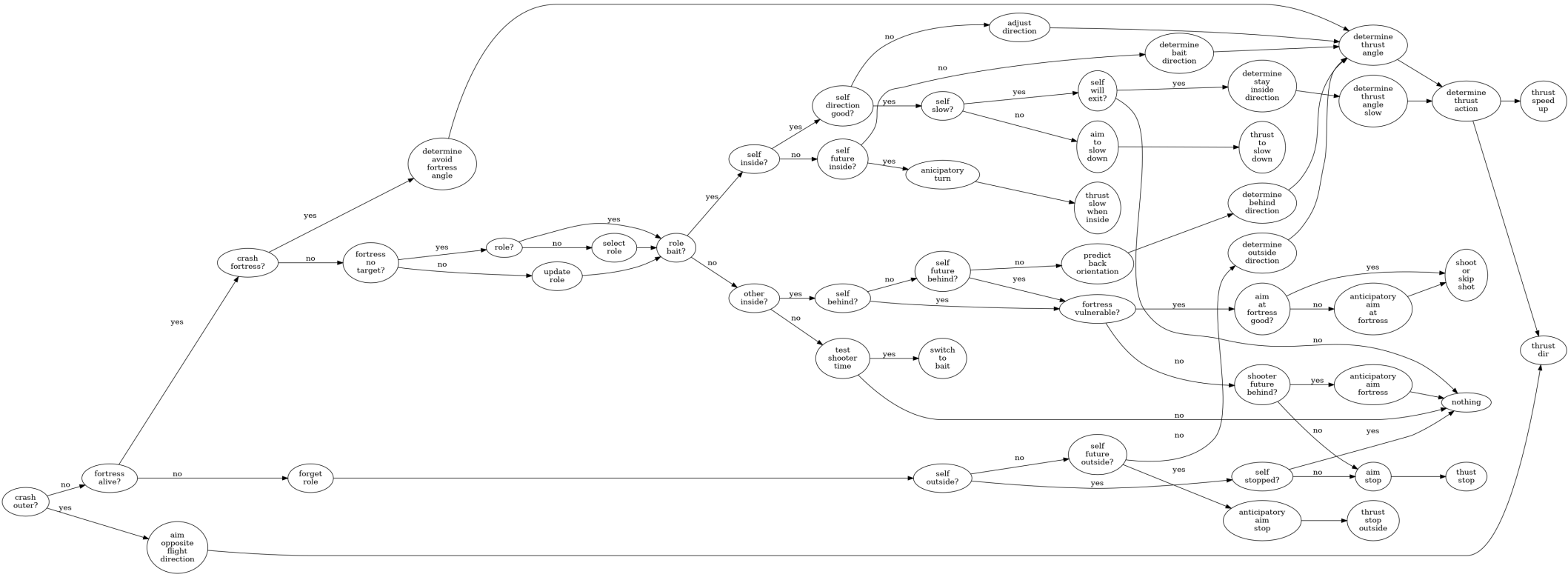


ACT-R Model: Full Operator Tree



ACT-R Model: Production Compilation

P1: Trigger operator retrieval

R1: Retrieve operator

P2: Execute operation

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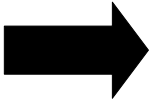


P2b: Directly execute operation

ACT-R Model: Control Tuning

- Control tuning tunes parameters to the specific task from feedback about reward rate:
  1. Assume a quadratic relationship between parameter values and reward rate
  2. Assume an exponentially decaying noise around reward rate
  3. Pick a parameter value and sample its reward for a certain period (positive and negative feedback associated with events)
- Example: Learning **bait speed (**positive feedback from fortress missiles and negative feedback from dying)

ACT-R Model: Control Tuning

- Stochastic gradient descent: Adjust control parameter as a function of **error magnitude** and **error direction** after an action
- Example: learning when to **release key press** when turning as a function of feedback about **how far off** the resultant orientation was from the target orientation and whether it **under- or overshot** the target

ACT-R Model: Anticipatory Actions

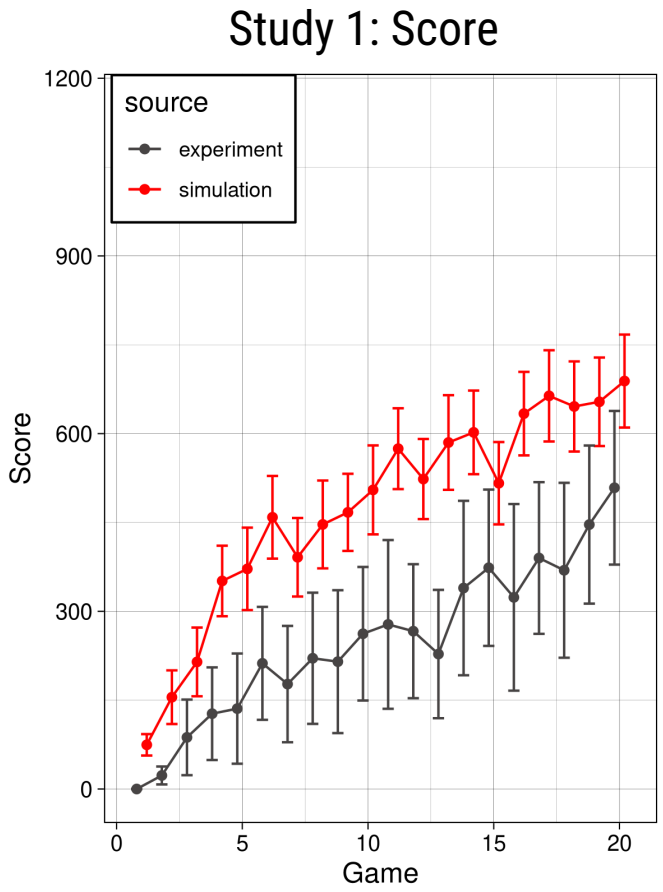
- All anticipatory actions in model rely on **motion extrapolation** based on the ship's current position and speed:
  1. Avoid crashing into obstacles
  2. Determine aim at fortress at time of shot
  3. If bait's future location is inside the hexagon, prepare to slow down
  4. If future location is outside of hexagon, prepare to stop

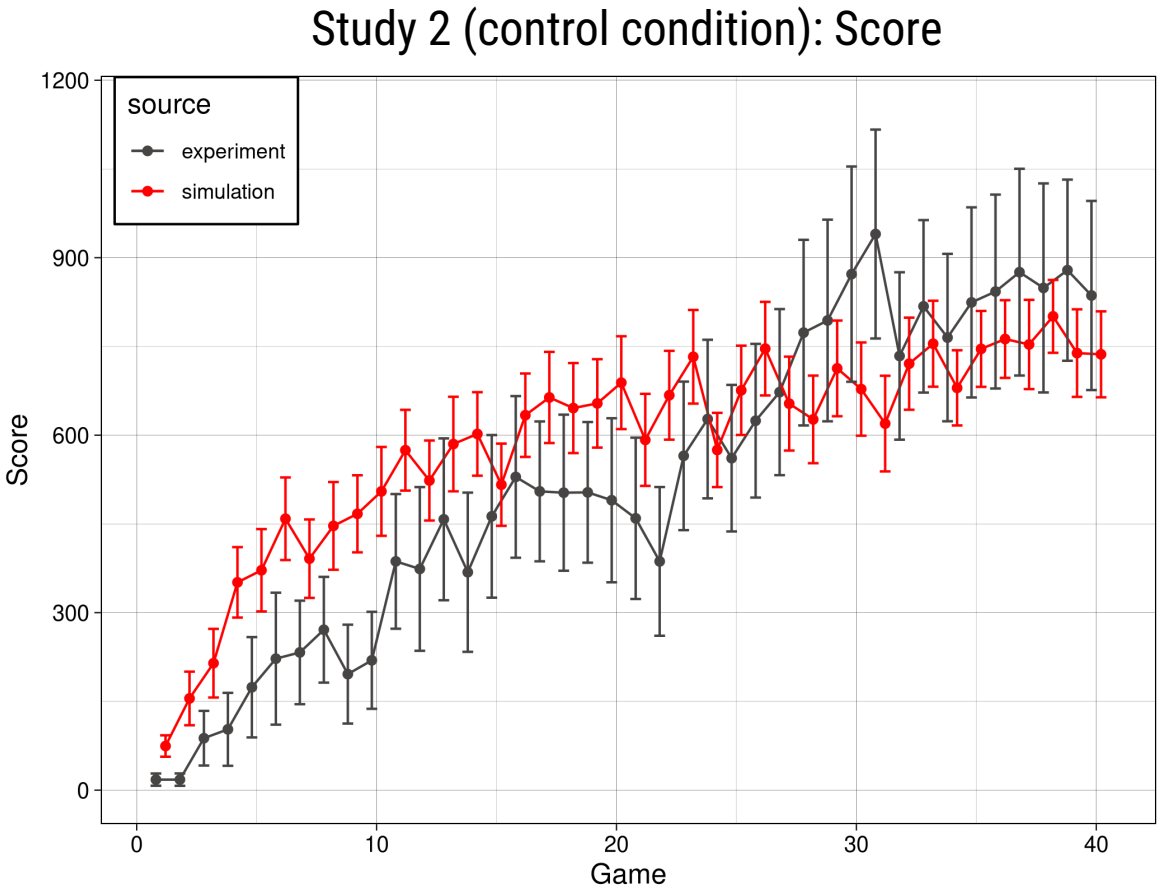
ACT-R Model: Role Adoption

Role adoption is modeled through **reinforcement learning.** Two productions that select bait/shooter compete with each other. The production utility is updated:

- Each fortress kill brings positive reward
- A role switch brings negative reward

ACT-R Model: Performance





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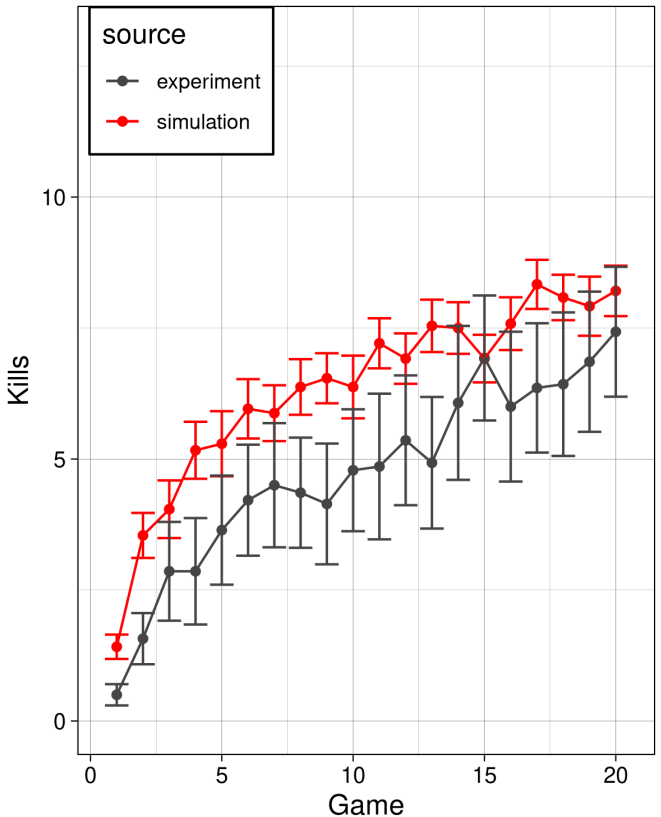
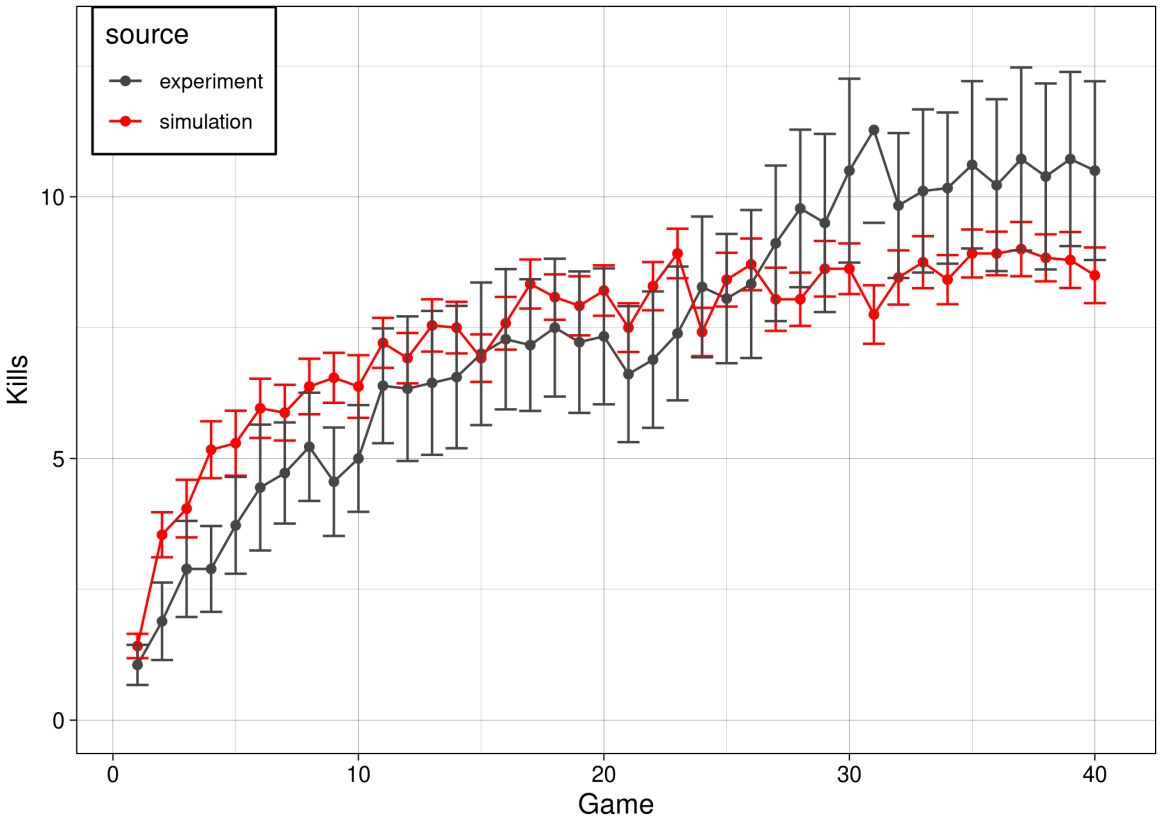


Study 2 (control condition): Kills



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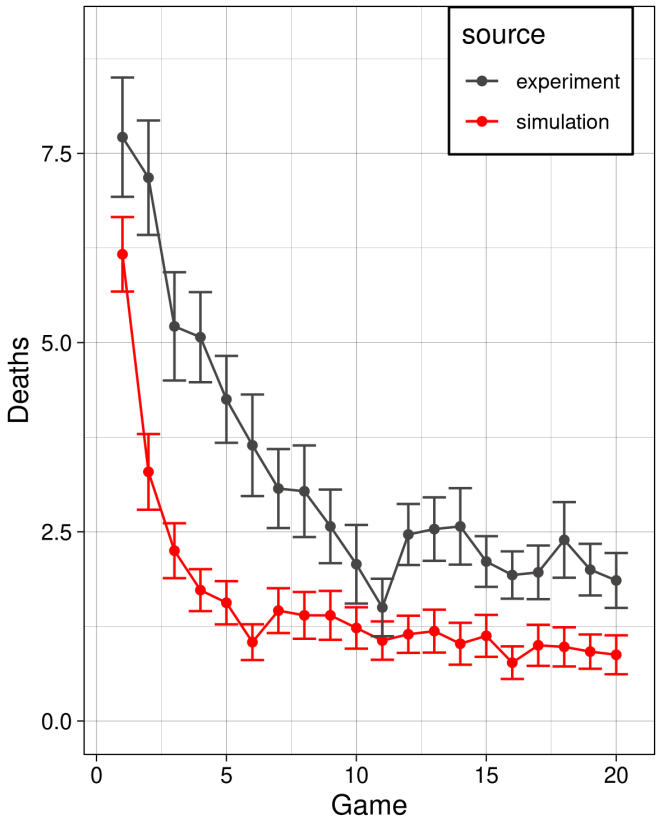

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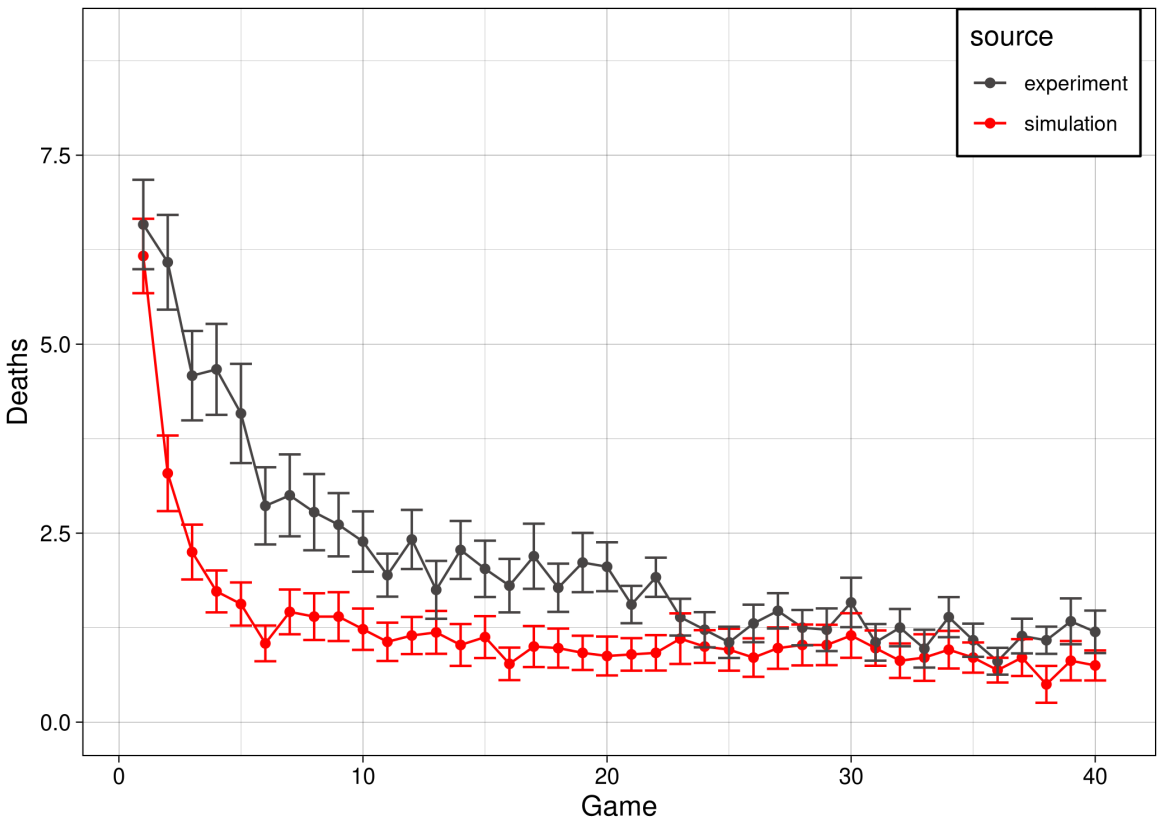
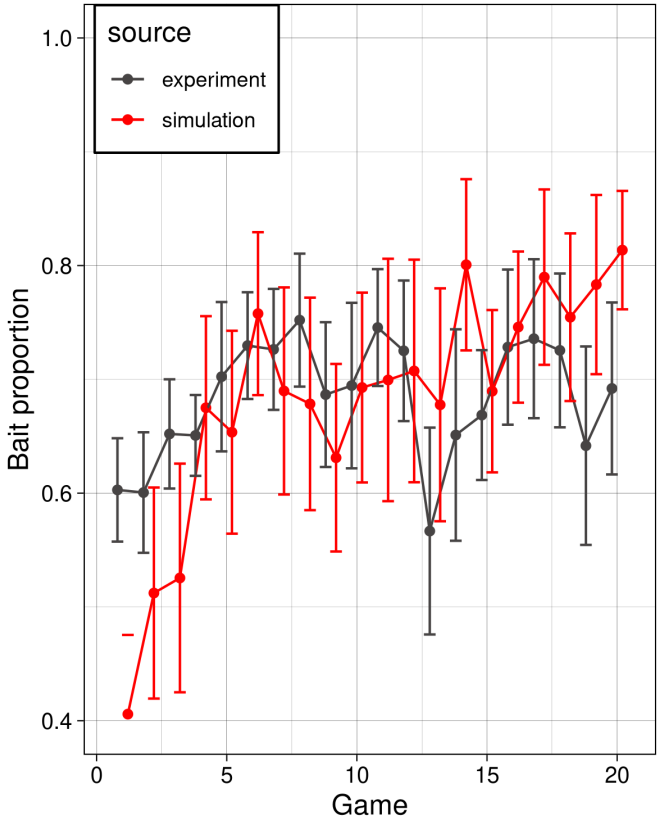
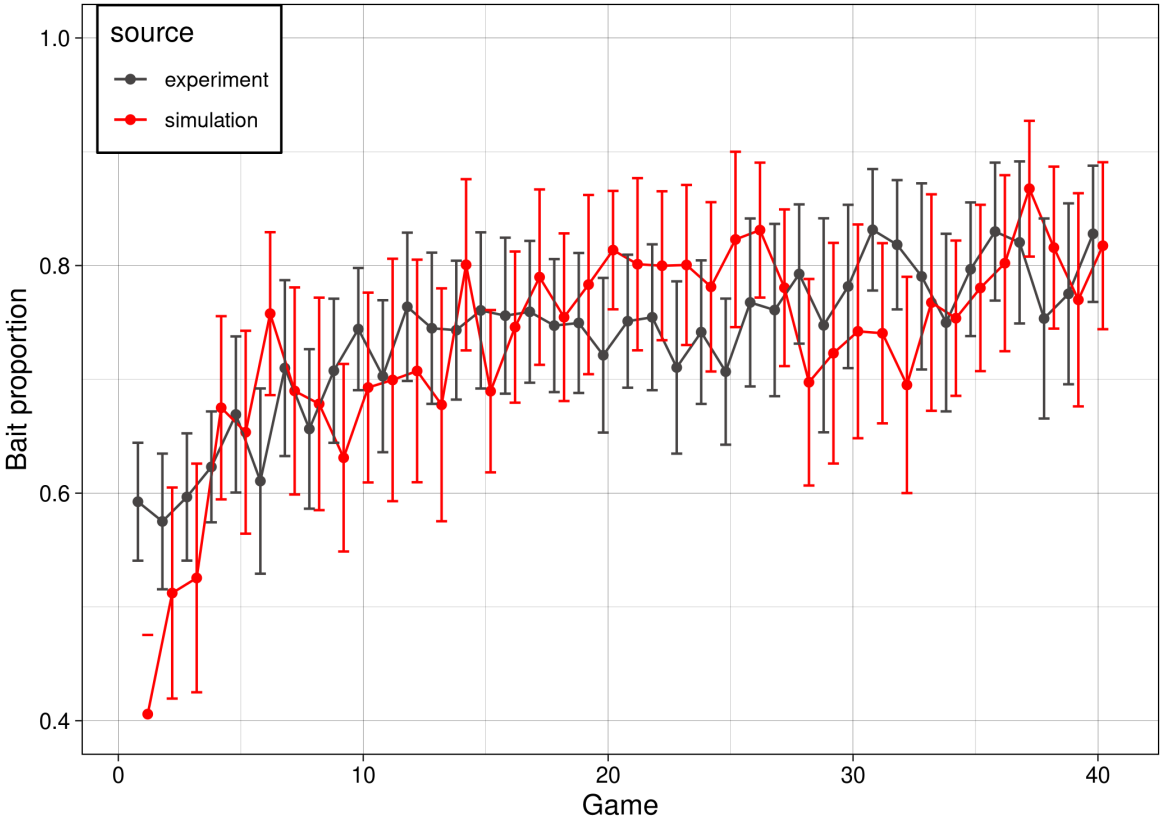


ACT-R Model: Role Consistency

Study 1: Bait proportion



Study 2 (control condition): Bait proportion








Thank you