

IOWA STATE UNIVERSITY

Department of Industrial and Manufacturing Systems Engineering

Evaluating the Hurricane Decision Simulator

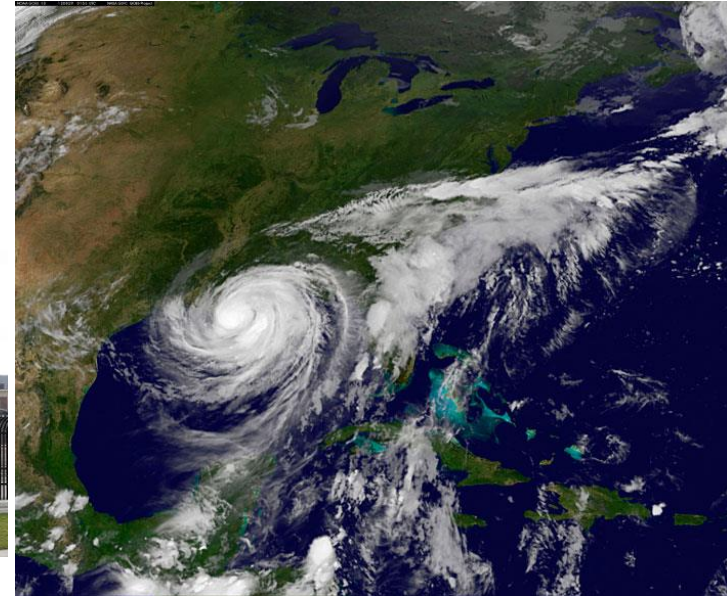
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U.S. Marine Forces Reserve (MFR)



MFR Decision Support Matrix

Hours before arrival of 39-mph winds

1. 96 hours: Send advance emergency relocation staff (ERS) to alternate headquarters
2. 96 hours: Send liaison officers to local municipal emergency operations centers
3. 72 hours: Send rest of ERS to alternate headquarters
4. 72 hours: Activate remain behind element to stay if evacuation ordered
5. 60 hours: Evacuate or shelter in place
6. 48 hours: Transfer command and control to alternate headquarters

Hurricane Decision Simulator

- Training tool to make hurricane preparation decisions
- Key characteristics
 - Simulated storms (storm and forecasts)
 - User decisions
 - Actions of other entities
 - Consequences of storm plus decisions

Regnier, E., & MacKenzie, C.A. (2017). The Hurricane Decision Simulator: A tool for Marine Forces in New Orleans to practice operations management in advance of a hurricane. *Manufacturing & Service Operations Management*. In press.

Hurricane Decision Simulator

The screenshot displays the Hurricane Decision Simulator interface. At the top, the browser address bar shows 'eddy.nps.edu/hurricaneSim/simulation#'. The main header is 'HURRICANE DECISION SIMULATOR'. Below this, there are tabs for 'About' and 'Help'. The left sidebar contains a 'Record of Events' section with a list of simulated events and their probabilities. The main content area shows 'PROBABILITIES (of Winds Exceeding Threshold)' with tabs for '39 mph', '58 mph', '74 mph', 'Cone', and '5 Jul 1200'. A map displays a simulated storm with concentric rings of probability. A 'Decision' overlay is present, asking: 'Do you want to deploy the ADVON (19 personnel) for about \$25,000?'. Below the question, it states: 'The HURREVAC timeline recommends deploying the ADVON 96 hours prior to the arrival of tropical storm force winds if hurricane force winds are expected to follow.' There are 'YES' and 'NO, CONTINUE' buttons. At the bottom, a 'CURRENT UPDATE' section shows: '120-hour probability of 39 mph winds affecting NOLA: 77%'. It also includes a table with storm details: Expected Landfall (70 hrs at 30.1°N x 85.5°W), Storm Center (26.7°N x 88.3°W), Radius of Max Winds (69 mi), and Max Sus. Winds (50 mph). A 'SHOW MAP' button is also visible.

Simulated storms...with forecasts

Six key decisions

and follow-on actions

Simulation Over

Results:

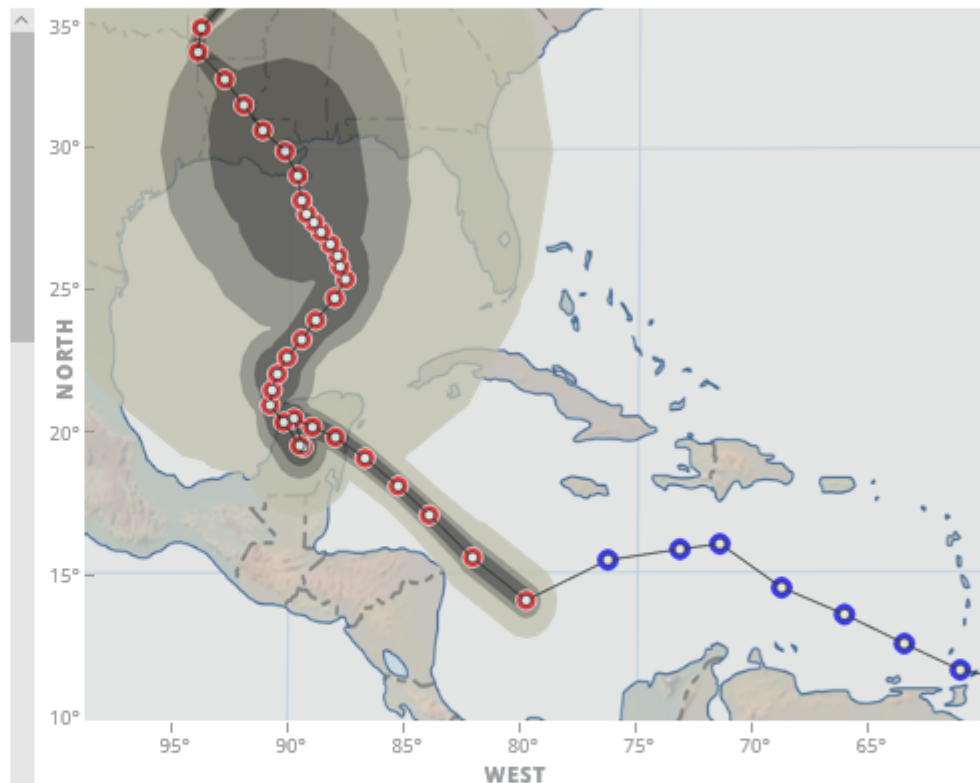
The storm made landfall at 30.0°N and 90.3°W as a Category 2 hurricane. The storm made landfall on 11 Aug 0800, 246 hours after the NHC's first forecast of this storm. NOLA experienced 104 mph winds, 12 hours before the storm made landfall. Landfall occurs when the center of the storm reaches the coastline, but high winds often reach land much earlier, especially for large or intense storms. Tropical storm force winds (39 mph or greater) reached NOLA about 24 hours before the storm made landfall.

The storm surge was 4.0 feet and occurred at low tide.

You deployed the ADVON 54 hours before NOLA experienced 39 mph winds.

You deployed liaison officers to local municipal EOCs 48 hours before NOLA experienced 39 mph winds.

You deployed the rest of the ERS to the alternate HQ 42 hours before NOLA experienced 39 mph winds.



REVIEW

NEW SIMULATION

Use by the Marines

- Individual training by crisis action team and emergency relocation team (almost 200 people) since Fall 2015
- Used in developing annual (team) specialized hurricane exercises
- Expanded to Hialeah Reserve Training in Florida in June for command turnover

Research question

- Does the Hurricane Decision Simulator help people make better decisions?
- How does the Hurricane Decision Simulator impact or change people's decision making?

Subjects

- Engineering economy class in Spring 2017
- 157 undergraduate students, engineering majors
- Mostly juniors and seniors

Text description (day 1)

- You are the Commander of U.S. Marine Forces Reserves (MARFORRES) whose headquarters are located in New Orleans, Louisiana. ...
- Tropical cyclone
 - Probability of tropical force winds
 - Probability of hurricane winds
 - Expected time to landfall
- Evacuation costs
- Marines timeline

Evacuate, shelter in place, neither?

Three scenarios

	Probability wind speed > 39 mph	Probability wind speed > 74 mph	Expected hours to landfall
Scenario 1	77	31	58
Scenario 2	84	22	59
Scenario 3	100	52	58

- Costs of evacuation = \$300,000 per day for 1-2 weeks
- Marines' timeline recommends evacuating 60 hours before arrival of winds

Experiment

- Introduction to the Hurricane Decision Simulator (HDS)
- Subjects practiced with HDS (~15 minutes)

Day 2

- Each subject made decisions for the exact same 5 storms in HDS
- Subjects recorded information
 - Details of the storm
 - Riskiness of storm
 - Subjective evaluation of decision-making processes
- Final 3 storms in HDS equivalent to text description on day 1

Hurricane Decision Simulator

The screenshot displays the Hurricane Decision Simulator interface. On the left, a 'Record of Events' sidebar lists simulated events with timestamps and probabilities. The main area shows a map of a simulated storm with concentric rings representing wind speed probabilities. A decision dialog box is overlaid on the map, asking for a decision on deploying ADVON personnel. A 'CURRENT UPDATE' box at the bottom provides specific data for the 120-hour probability of 39 mph winds affecting NOLA.

Record of Events

Event	Time	Probability
Current	70 hrs	77%
6 hrs ago	75 hrs	72%
12 hrs ago	79 hrs	75%
18 hrs ago	83 hrs	81%
24 hrs ago	88 hrs	60%

PROBABILITIES (of Winds Exceeding Threshold)

39 mph 58 mph 74 mph Cone 5 Jul 1200

Decision

Do you want to deploy the ADVON (19 personnel) for about \$25,000?

The HURREVAC timeline recommends deploying the ADVON 96 hours prior to the arrival of tropical storm force winds if hurricane force winds are expected to follow.

YES NO, CONTINUE

CURRENT UPDATE 5 Jul 1200 No Actions Details

120-hour probability of 39 mph winds affecting NOLA: 77%

Expected Landfall	Storm Center	Radius of Max Winds	Max Sus. Winds
70 hrs (at 30.1°N x 85.5°W)	26.7°N x 88.3°W	69 mi	50 mph

Key

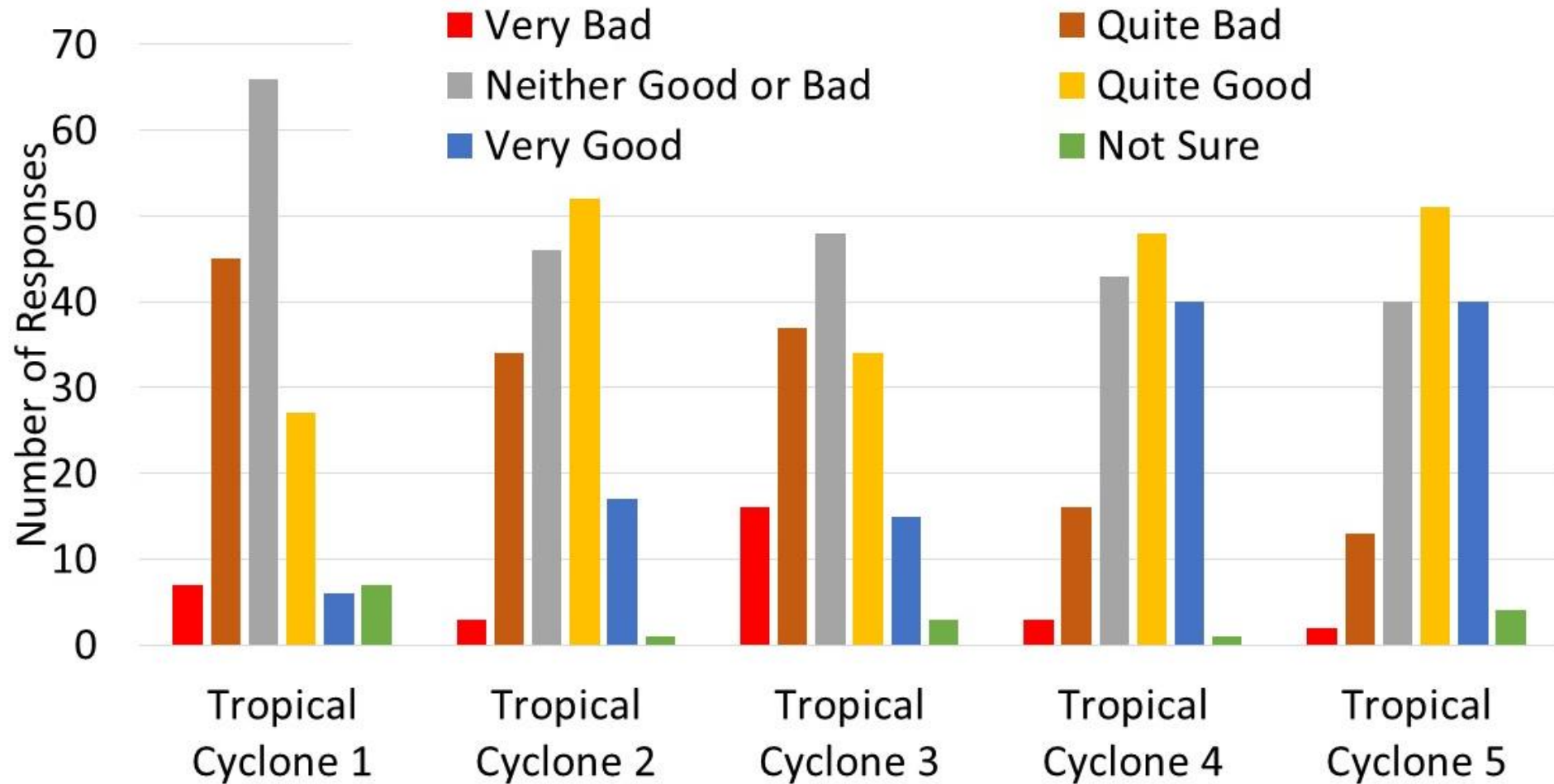
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 5%

Simulated storms...with forecasts

Six key decisions

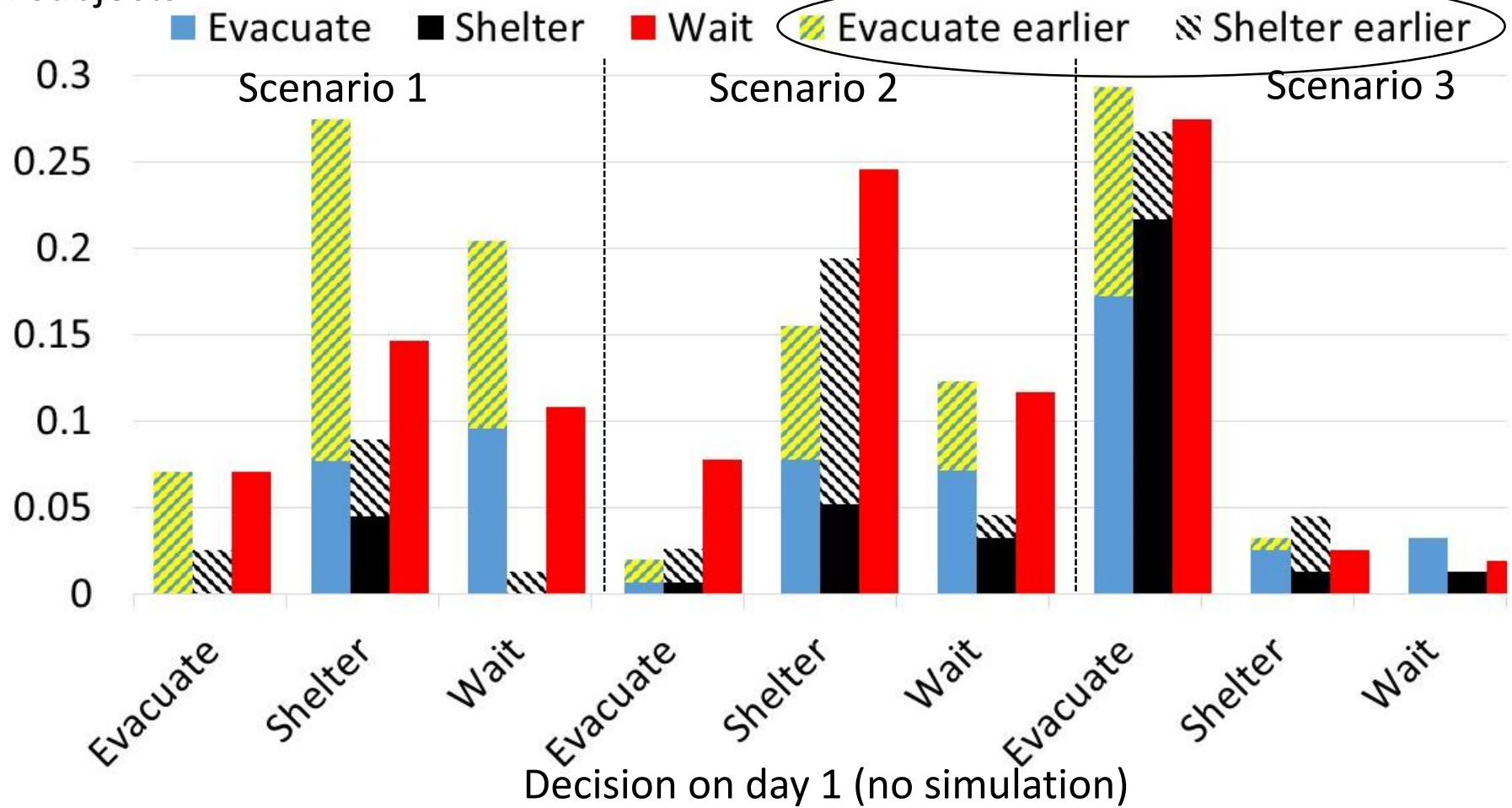
and follow-on actions

Subjective evaluation of decision-making process



Comparison of decisions (pre vs post)

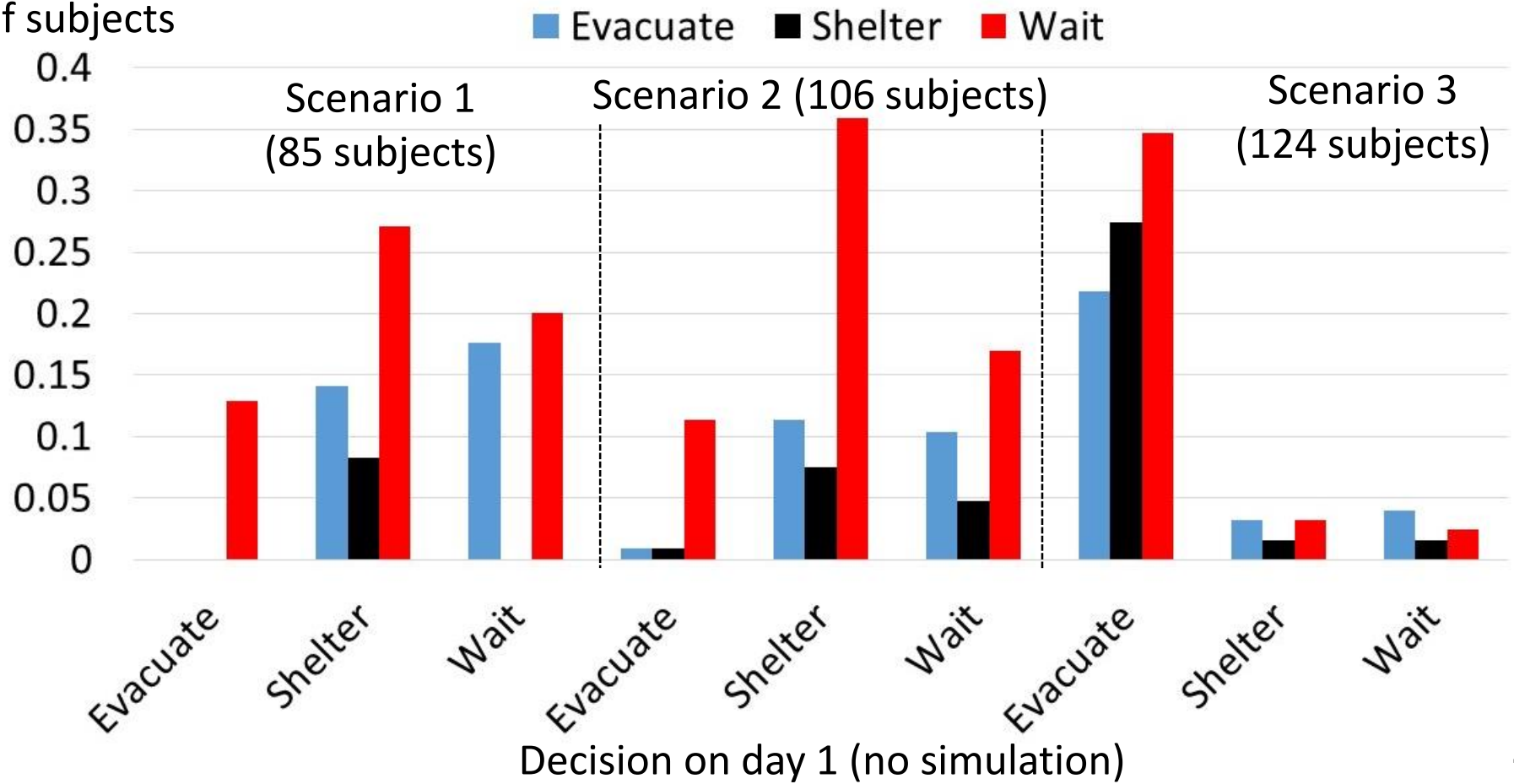
Proportion
of subjects



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Excluding subjects who evacuate / shelter earlier

Proportion of subjects



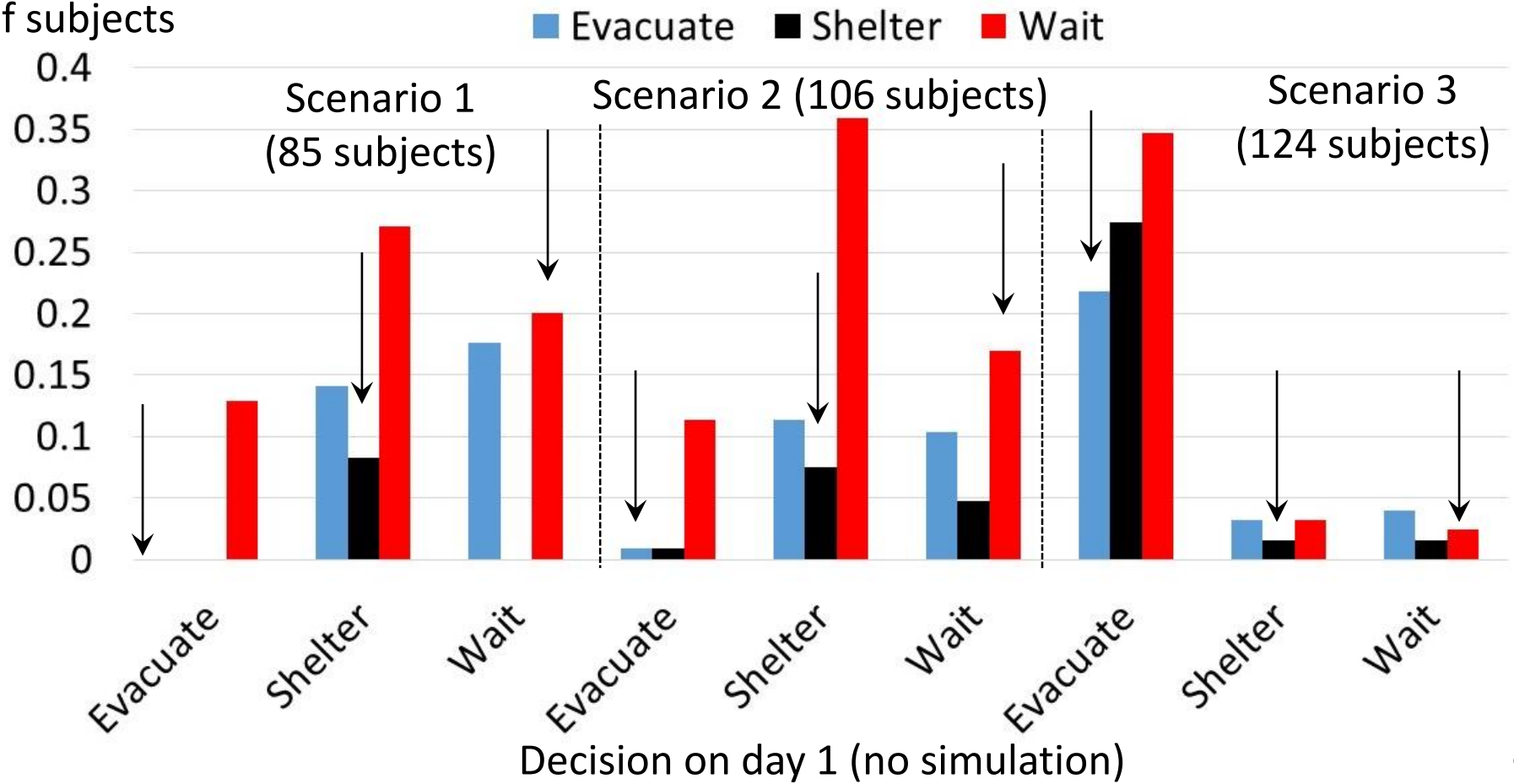
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Hypothesis 1

- Subject is more likely to make a different decision when using the Hurricane Decision Simulator
- Null: probability of making same decision on days 1 and 2 equals probability of making different decision

Hypothesis 1

Proportion
of subjects



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Hypothesis 1

- Subject is more likely to make a different decision when using the Hurricane Decision Simulator
- Null: probability of making same decision on days 1 and 2 equals probability of making different decision)

	p-value
Scenario 1	4E-06
Scenario 2	3E-06
Scenario 3	4E-10



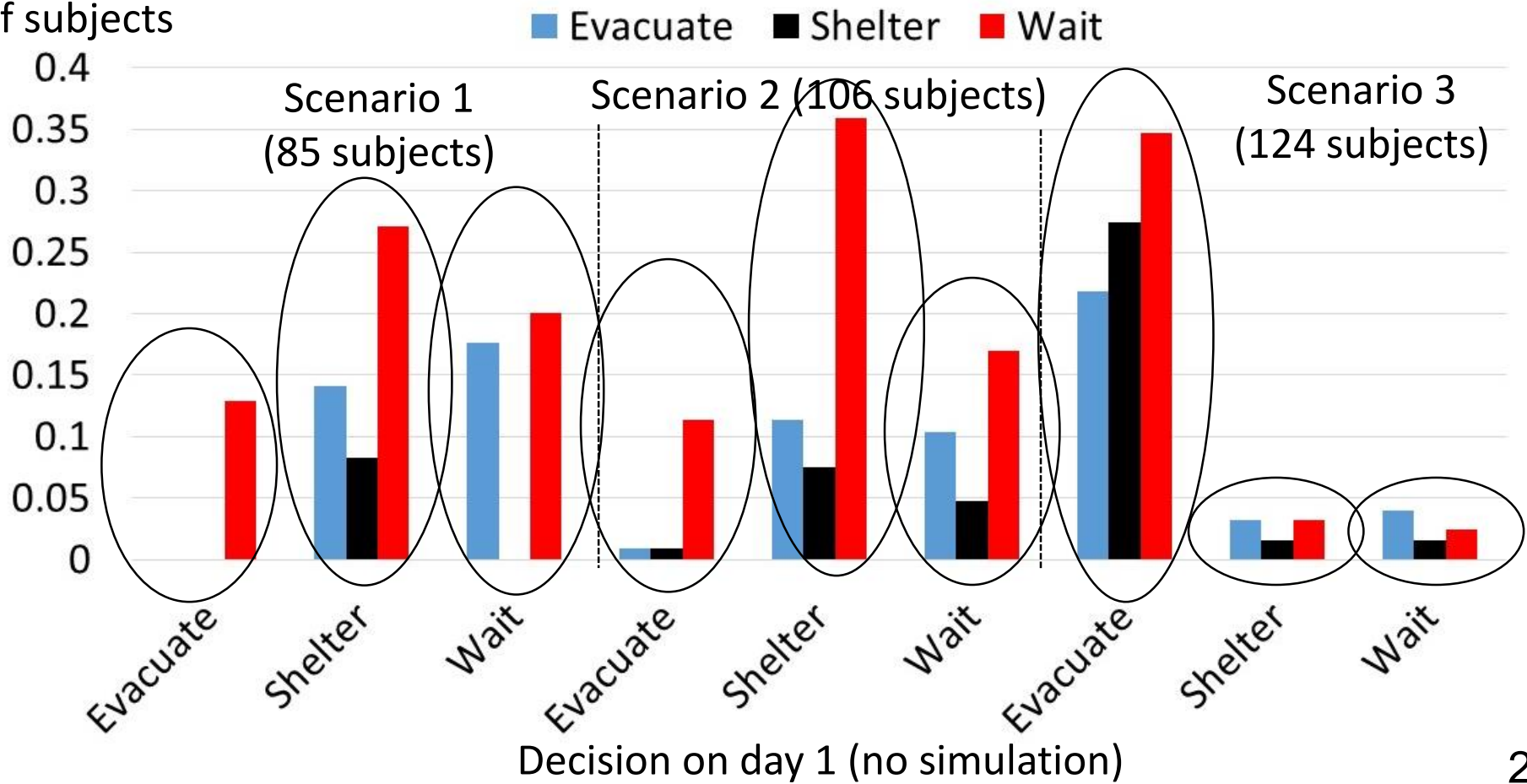
Reject null

Hypothesis 2

- Subject more likely to switch than what random chance would predict
- Null: probability of “Evacuate” equals probability of “Shelter” equals probability of “Wait”

Hypothesis 2

Proportion
of subjects



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Hypothesis 2 using Bayesian analysis

- Jeffrey's prior, $\mathbf{p} \sim \text{Dirichlet}(0.5)$
- Posterior, $\mathbf{p} \sim \text{Dirichlet}(0.5 + \text{number of subjects})$

	Given day 1 decision, probability 3 decisions on day 2 are equally likely		
Day 1 decision	Evacuate	Shelter	Wait
Scenario 1	0	4E-4	0
Scenario 2	2E-5	0	9E-4
Scenario 3	0.01	0.11	0.07

Based on 200,000 simulations of posterior distribution

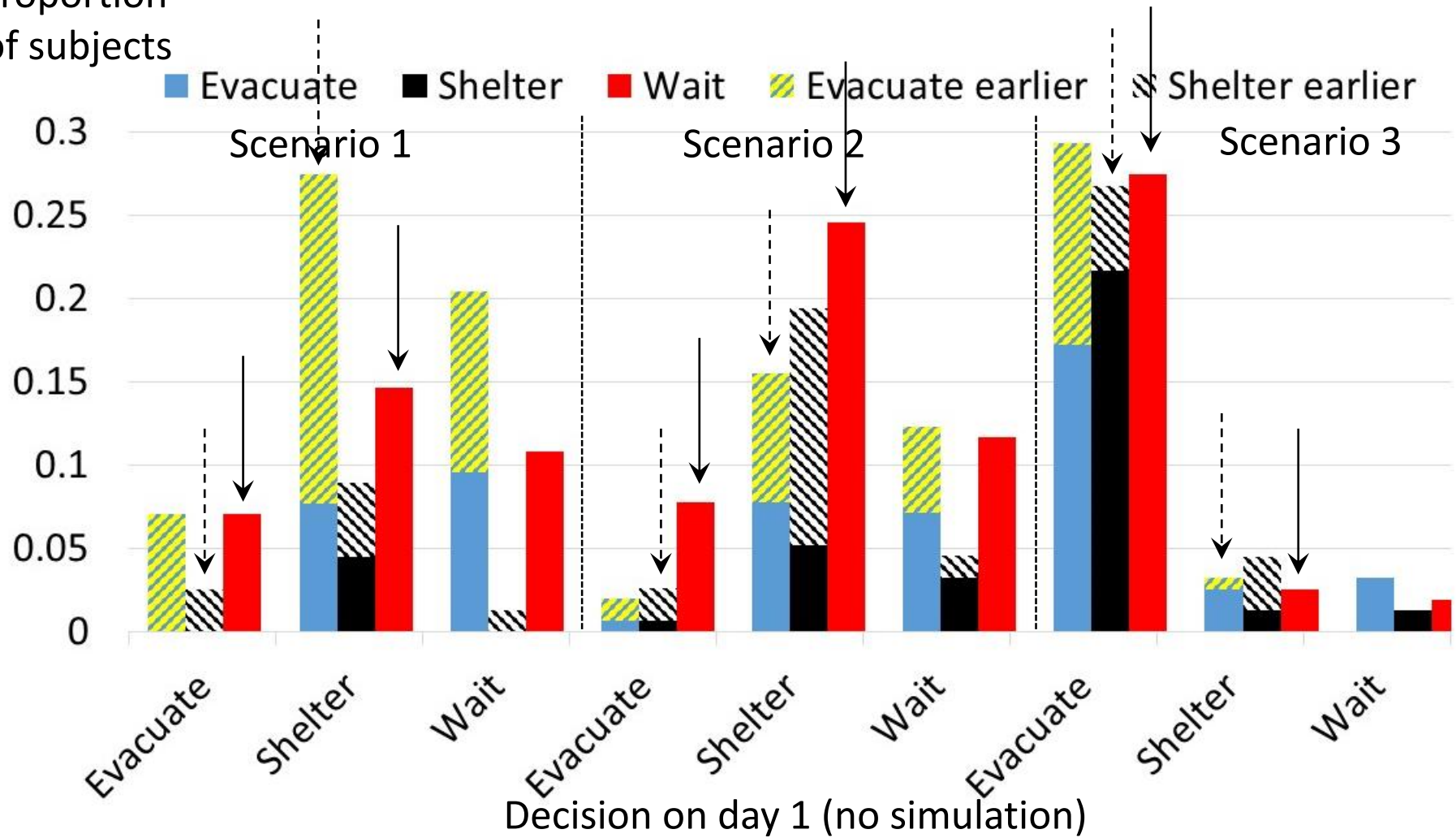
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Hypothesis 3

- Given that a subject switches between days 1 and 2, more likely that a subject switches to “Wait”
- Null: probability of switching from “Evacuate” to “Shelter” or from “Shelter” to “Evacuate” equals probability of switching to “Wait”

Hypothesis 3 (data for all subjects)

Proportion
of subjects



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Hypothesis 3 using Bayesian analysis

- Jeffrey's prior, $\mathbf{p} \sim \text{Dirichlet}(0.5)$
- Posterior, $\mathbf{p} \sim \text{Dirichlet}(0.5 + \text{number of subjects})$

	Given evacuate on day 1, $P(\text{shelter} > \text{wait})$ on day 2	Given shelter on day 1, $P(\text{evacuate}$ $> \text{wait})$ on day 2
Scenario 1	0.034	0.99
Scenario 2	0.021	0.038
Scenario 3	0.46	0.63

Based on 200,000 simulations of posterior distribution

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Conclusions

- People that practice with the Hurricane Decision Simulator (HDS) feel more comfortable making decisions in that context
- Impact of practicing with HDS
 - People seem more likely to switch their decisions after practicing with HDS
 - Choosing decision with HDS seems more than just random chance
 - HDS may slightly influence people to wait to evacuate or shelter, especially for difficult decisions

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