Reactive or Proactive?
How Robots Should Explain Failures

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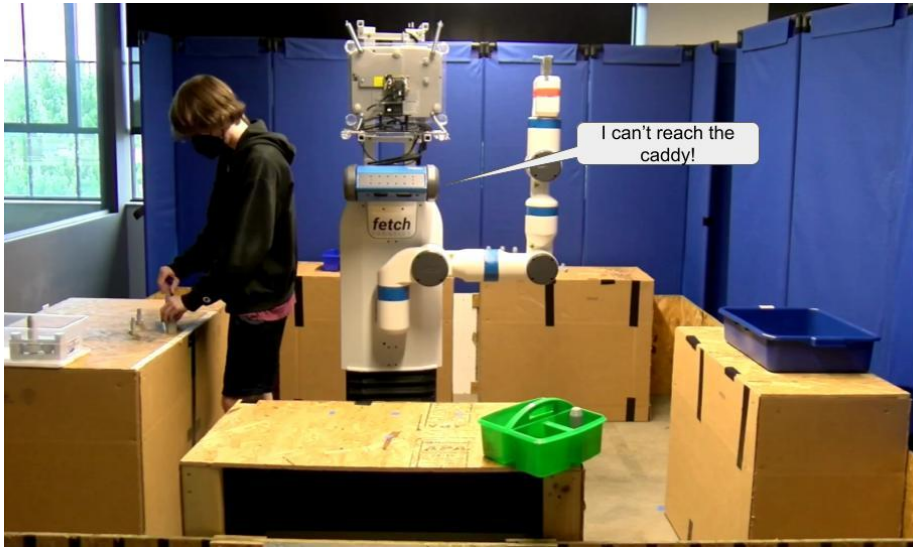
Motivation

Robots are increasingly being deployed in shared human-robot environments

- Hospitals
- Public spaces
- Warehouses / Manufacturing facilities

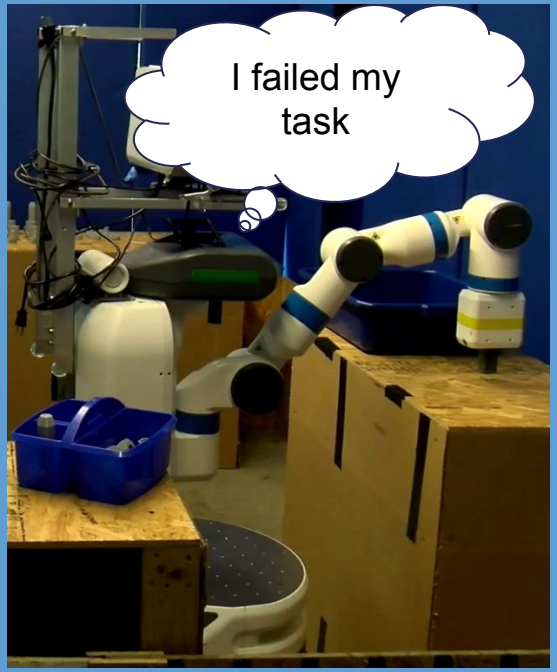


Robots may require assistance

- Unforeseen circumstances

Explainable Systems

Reactive

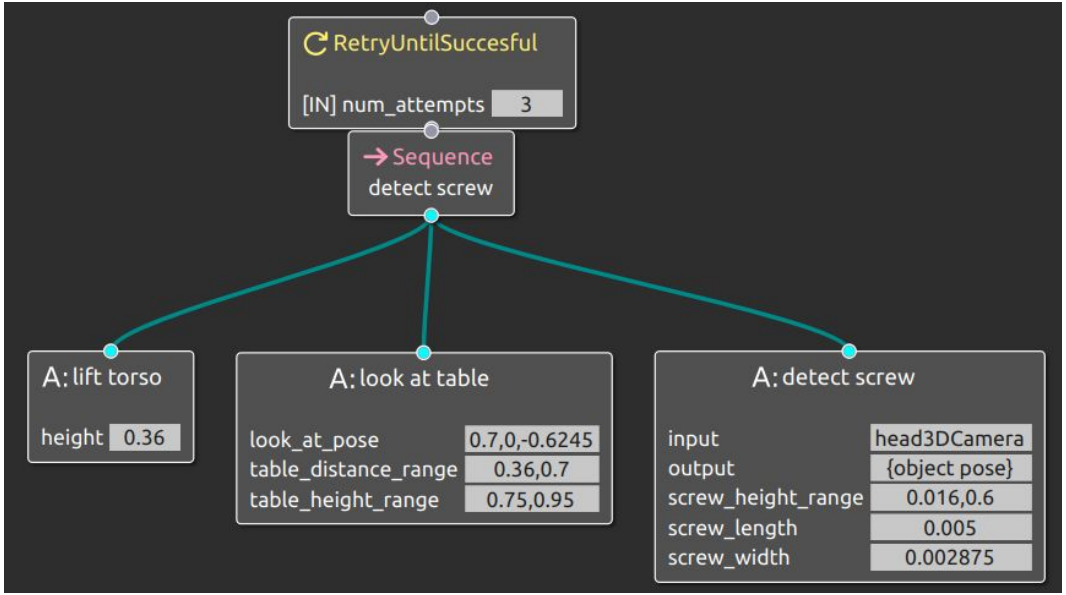


Proactive

Reactive Explanation Architecture

Subgoal

Actions

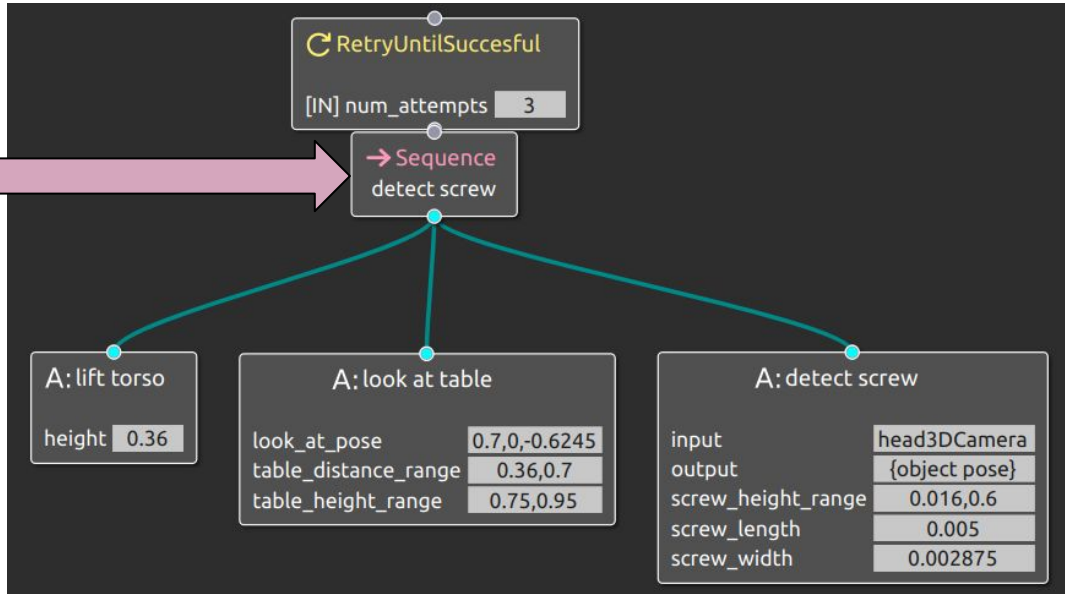


Zhao Han, Daniel Giger, Jordan Allspaw, Michael S Lee, Henny Admoni, and Holly A Yanco. **Building The Foundation of Robot Explanation Generation Using Behavior Trees.** A*CM Transactions on Human-Robot Interaction (THRI)* 10(3): 1–31, 2021.

Reactive Explanation Architecture

Subgoal

Actions



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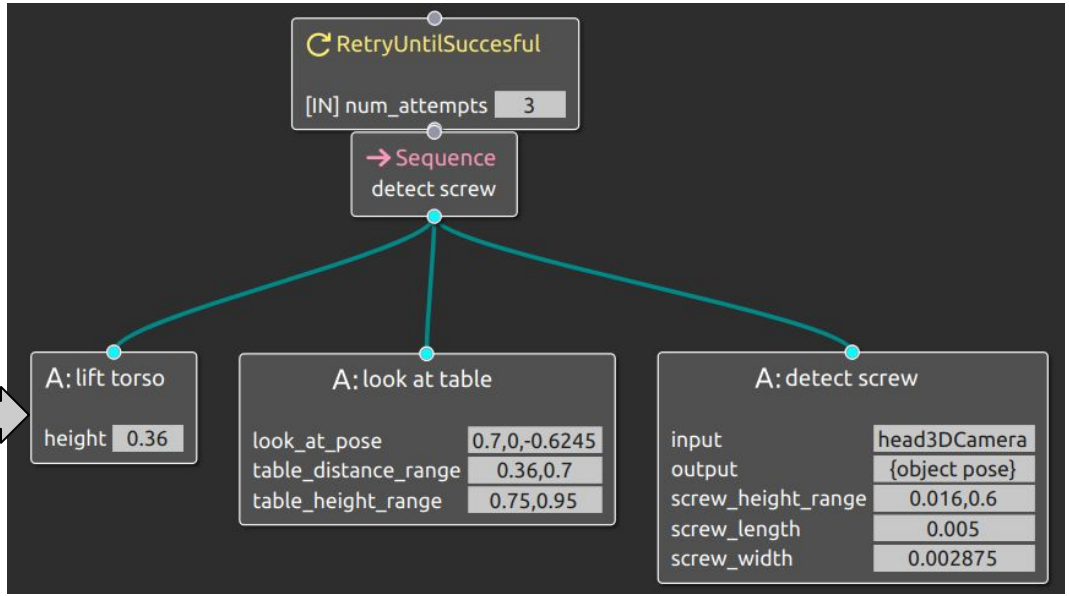
Reactive Explanation Architecture

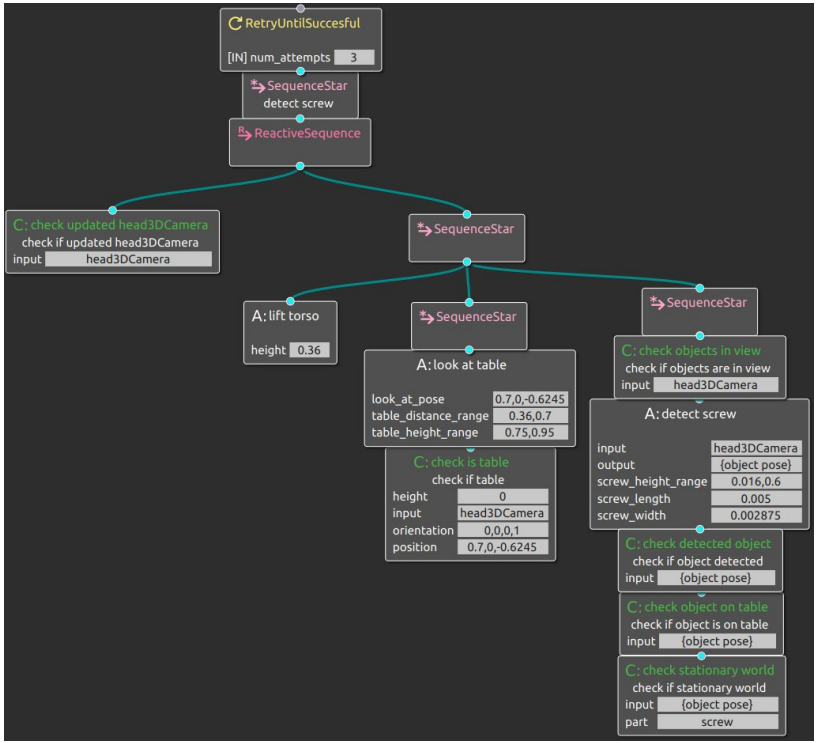
Subgoal

Actions



Zhao Han, Daniel Giger, Jordan Allspaw, Michael S Lee, Henny Admoni, and Holly A Yanco. **Building The Foundation of Robot Explanation Generation Using Behavior Trees.** A*CM Transactions on Human-Robot Interaction (THRI)* 10(3): 1–31, 2021.

Proactive Explanation Architecture



Reactive Architecture

+

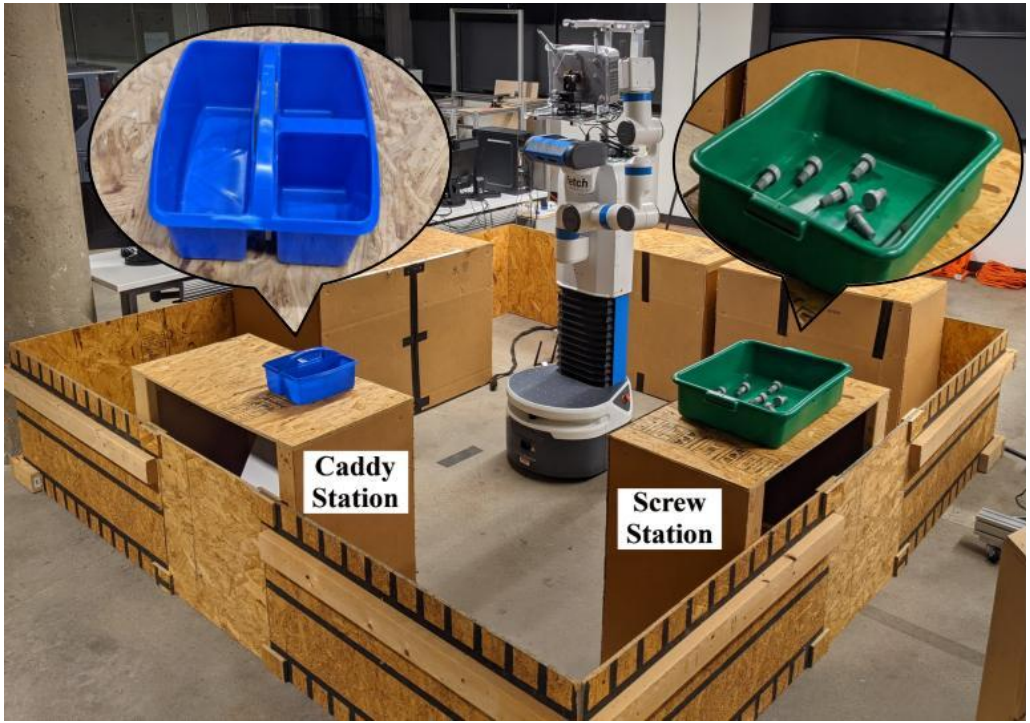
Assumption Checkers

For more on Assumption Checkers see:

- Alvika Gautam, Tim Whiting, Xuan Cao, Michael A. Goodrich, and Jacob W. Crandall. 2022. **A Method for Designing Autonomous Agents that Know Their Limits**. In IEEE International Conference on Robotics and Automation (ICRA).

- Xuan Cao, Alvika Gautam, Tim Whiting, Skyler Smith, Michael A. Goodrich, and Jacob W. Crandall. 2023. **Robot Proficiency Self-Assessment Using Assumption-Alignment Tracking**. IEEE Transactions on Robotics 39, 4 (2023), 3279–3298.

Scenario



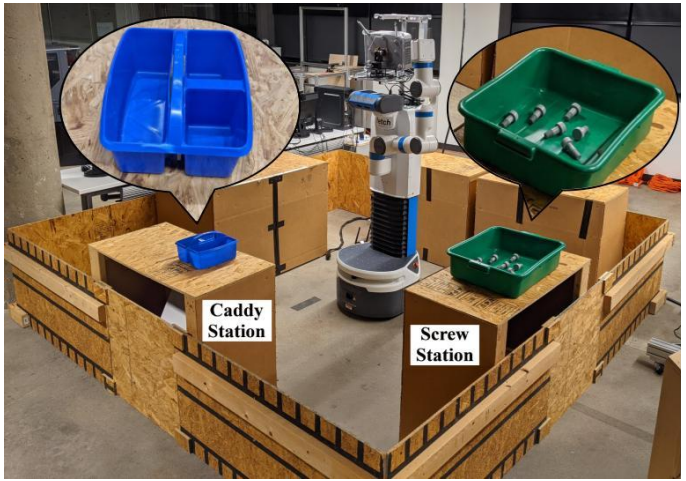
Study Design

3x3 Mixed Online Study Design (N=186)

System Type:
1. Base
2. Reactive
3. Proactive

X

Failure Type:
1. Screw Bin Empty
2. Screw Bin Moved
3. Caddy Out of Reach



Full videos for each of the 9 conditions:

System Conditions

System	Explanation Template	Timing
Base	I could not complete my task.	After Failure
Reactive	I could not [failed sub goal node name] because I was not able to [failed action node name].	After Failure
Proactive	[Assumption checker description] so I will not be able to [failed sub goal node name].	Before Failure

System Conditions

System	Explanation Template	Timing
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Measures

Human Perception (H1):

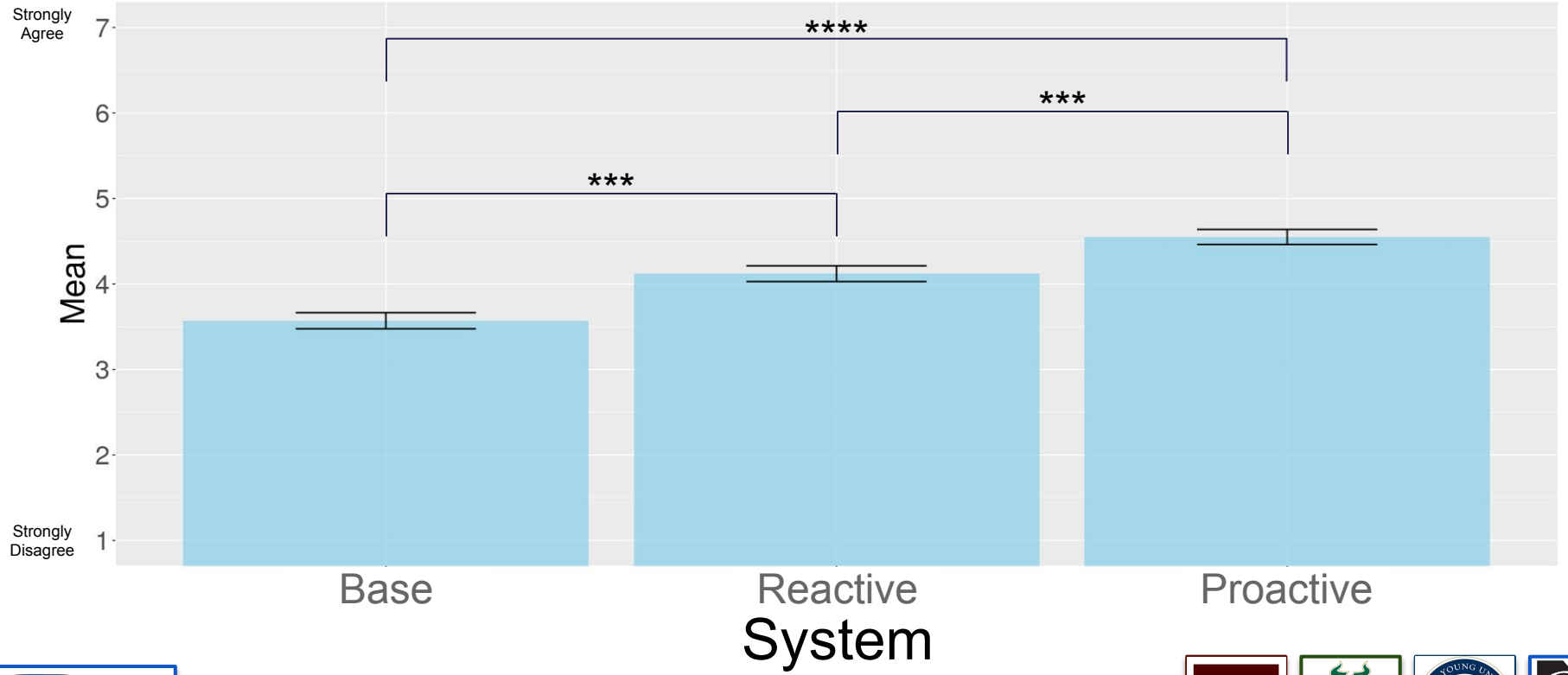
- Perceived Intelligence (Subjective)
- Perceived Trustworthiness (Subjective)

Explanation Quality (H2):

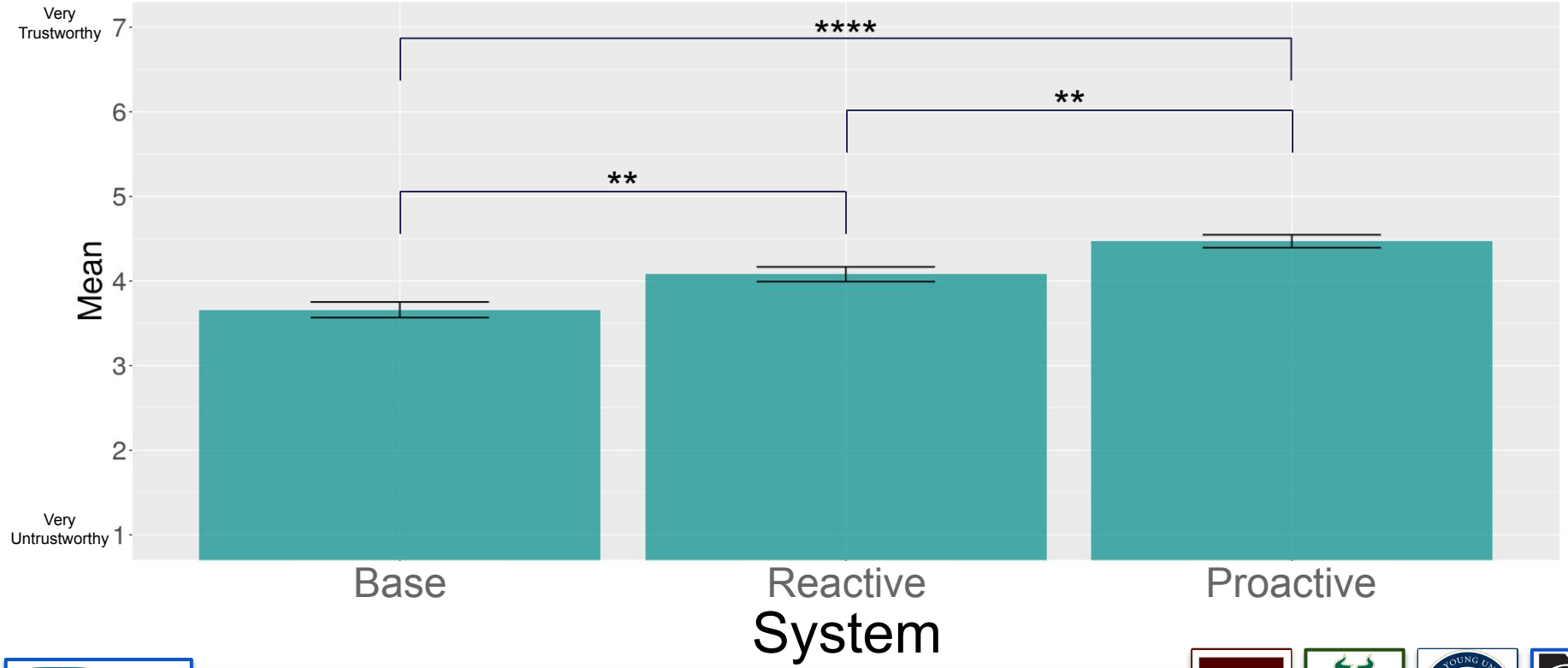
- Understandability (Objective & Subjective)
- Timing of Explanations (Subjective)

Preference (Subjective)

Perceived Intelligence



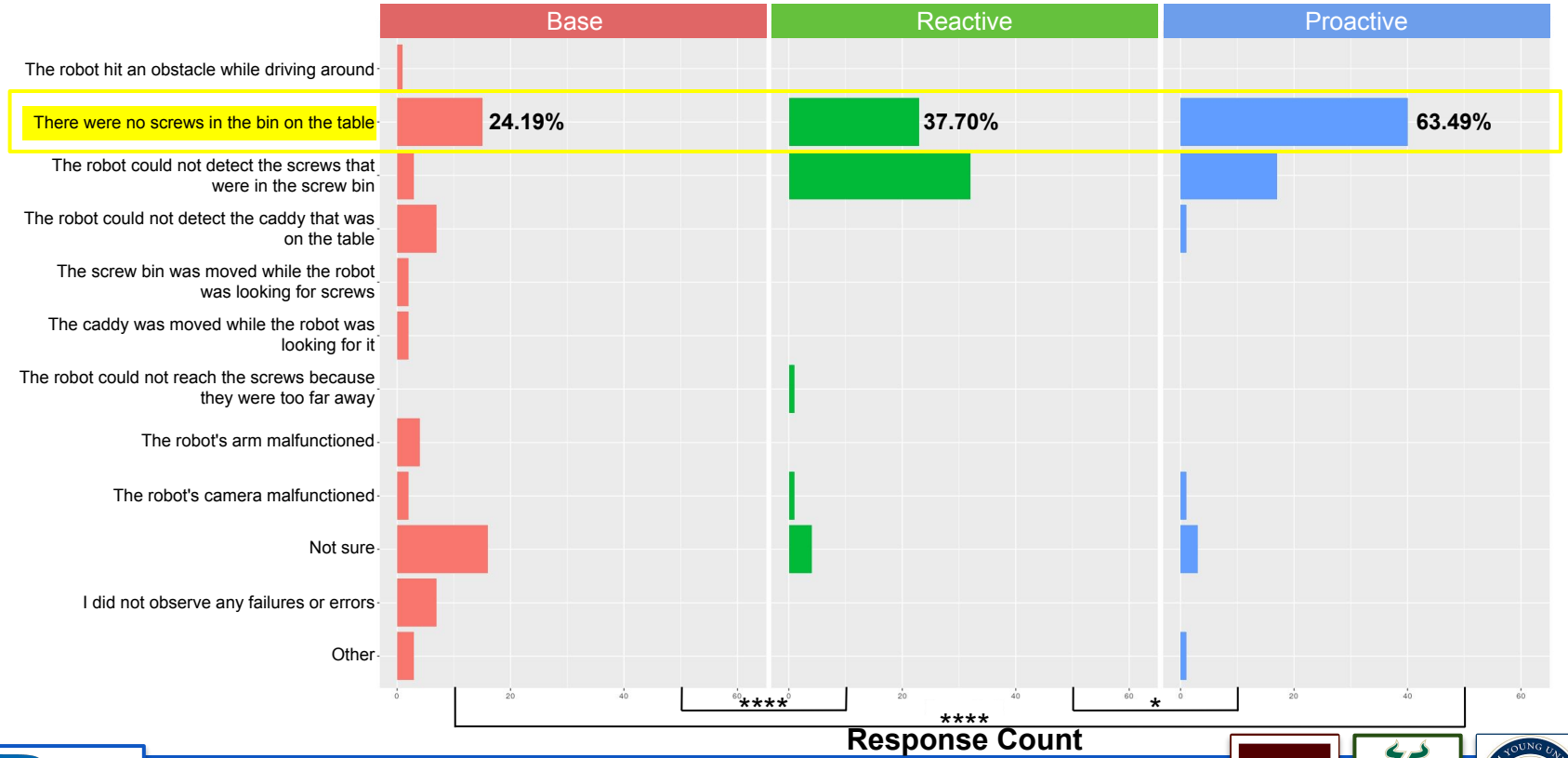
Perceived Trustworthiness



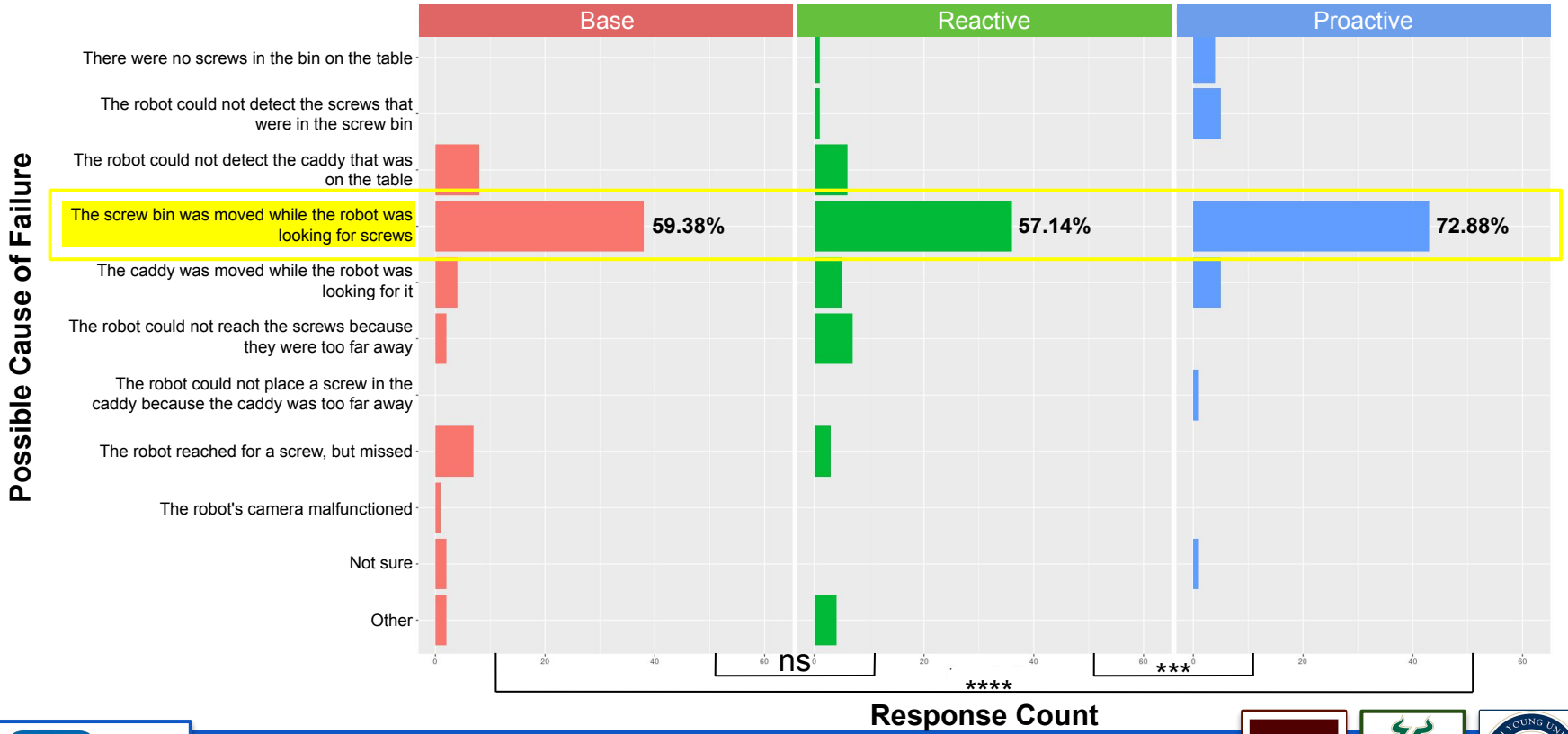
Understandability

	Possible Cause of Failure
	An obstacle was blocking the robot from driving to the table
	The robot hit an obstacle while driving around
Screw Bin Empty	There were no screws in the bin on the table
	There was no caddy on the table
	The robot could not detect the screws that were in the screw bin
	The robot could not detect the caddy that was on the table
Screw Bin Moved	The screw bin was moved while the robot was looking for screws
	The caddy was moved while the robot was looking for it
	The robot could not reach the screws because they were too far away
Caddy Out Of Reach	The robot could not place a screw in the caddy because the caddy was too far away
	The robot reached for a screw, but missed
	The robot dropped the screw
	The robot's arm malfunctioned
	The robot's camera malfunctioned
	Not sure
	I did not observe any failures or errors
	Other

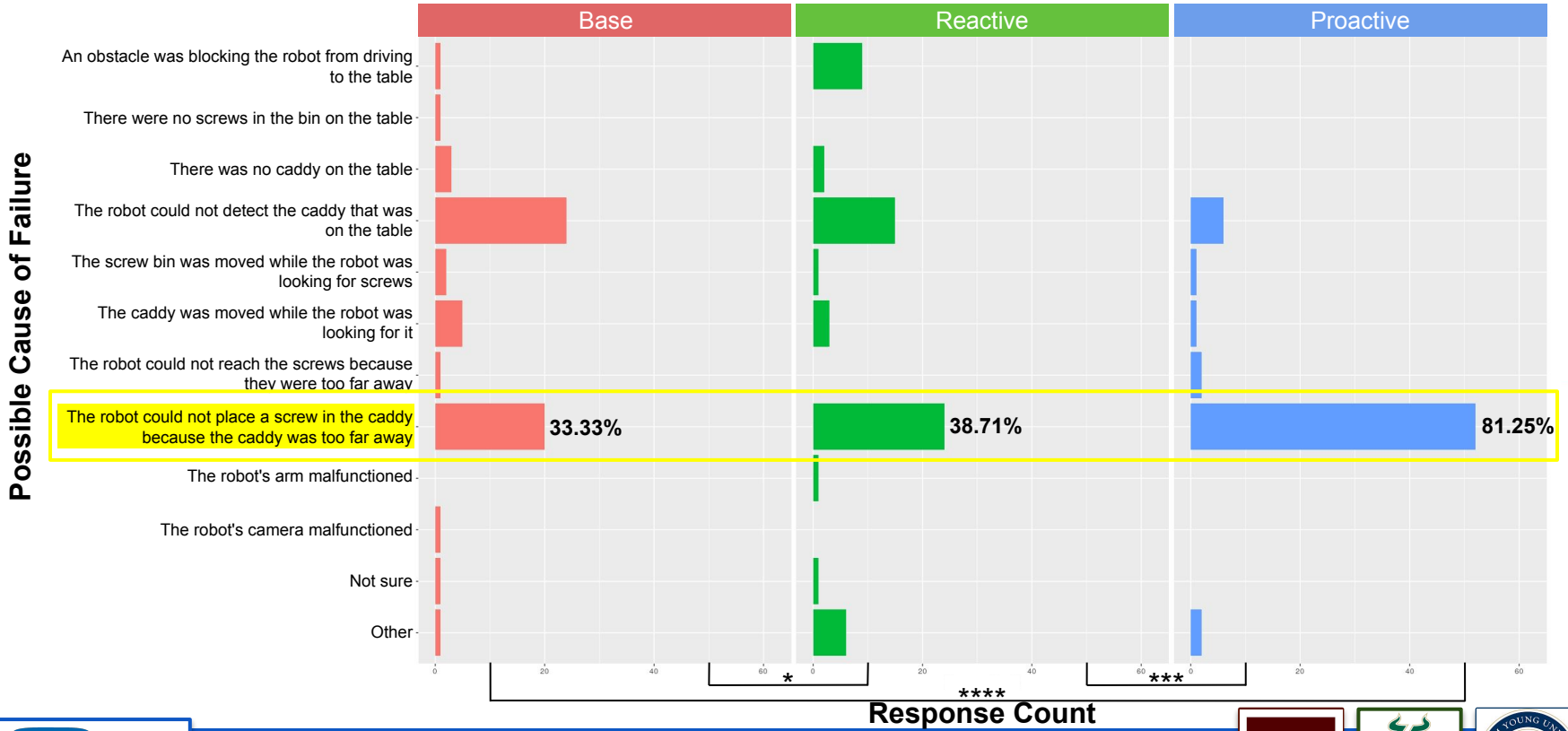
Understandability (Screw Bin Empty)



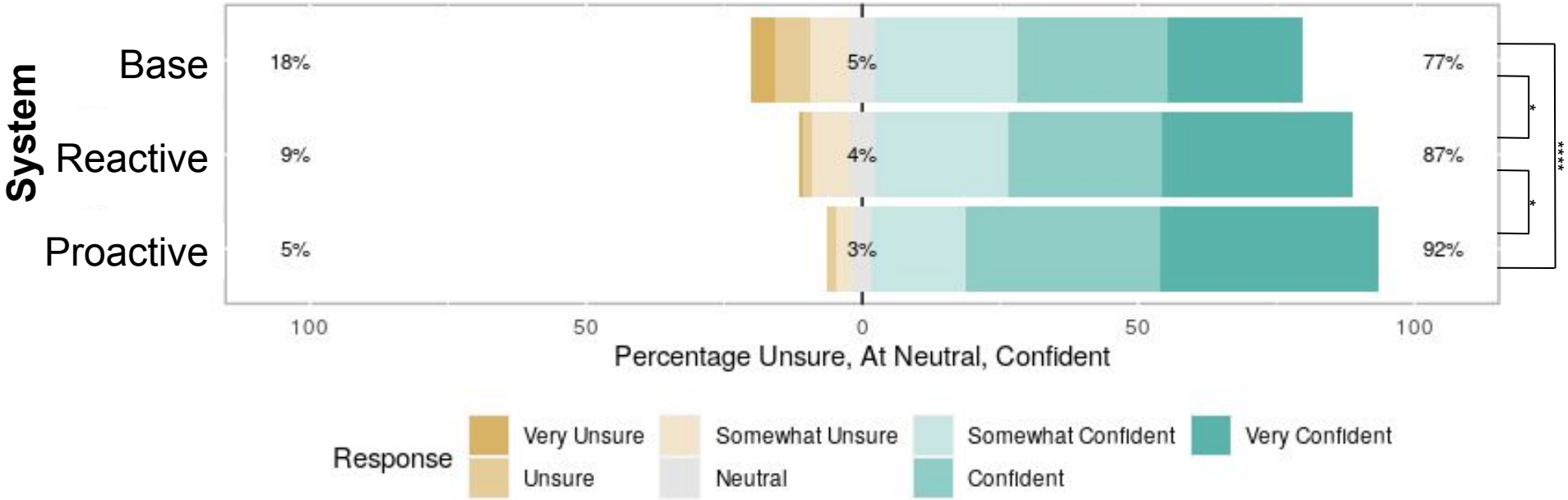
Understandability (Screw Bin Moved)



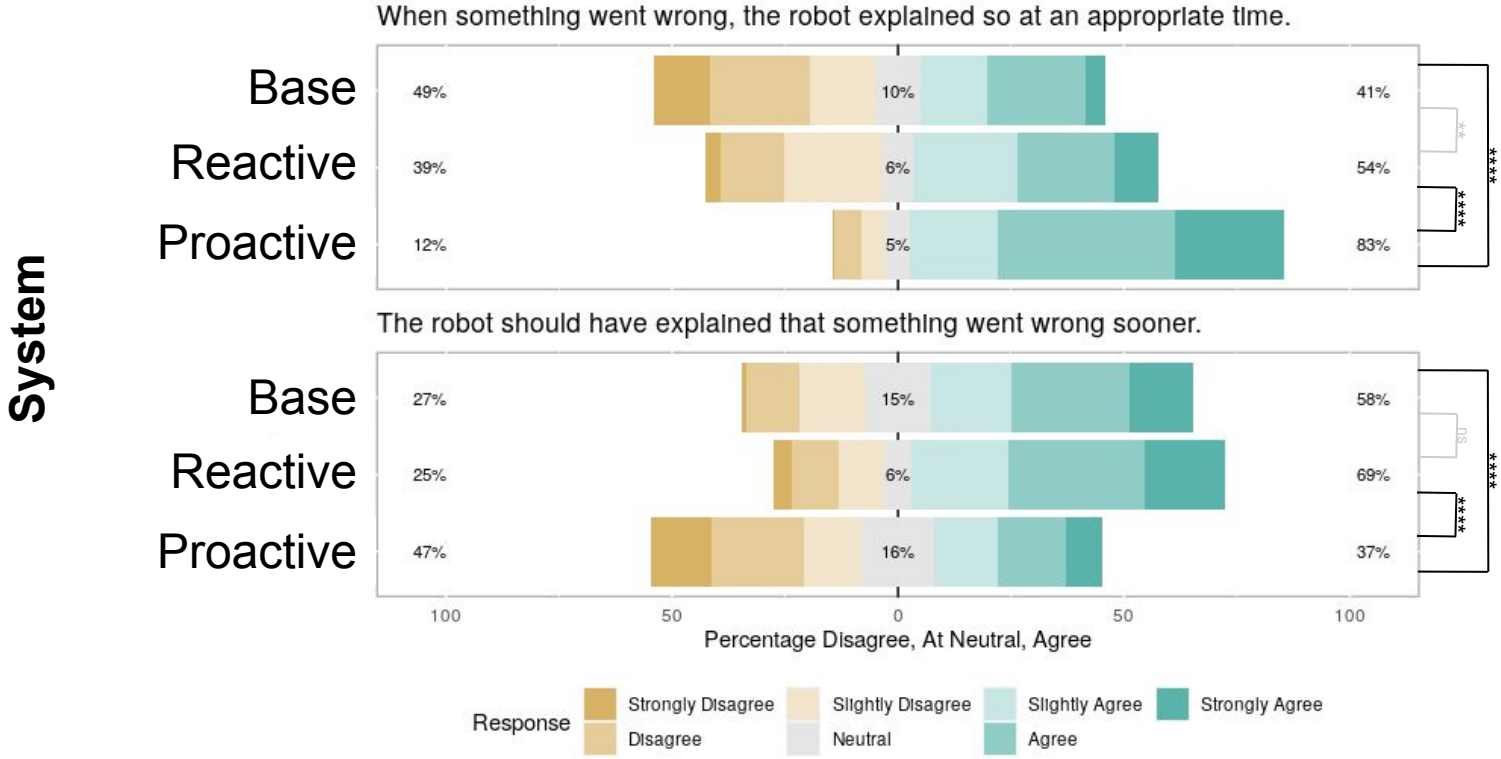
Understandability (Caddy Out of Reach)



Confidence in Understanding

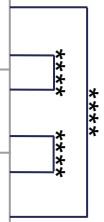


Timing of Explanations



Preference

System	Count	
Base	**7**	(3.7%)
Reactive	**49**	(26.3%)
Proactive	**127**	(68.3%)
Other	**3**	(1.6%)



Takeaways

Compared to Reactive systems, Proactive systems are:

1. Perceived as more intelligent
2. Perceived as more trustworthy
3. Understandable
4. Timely
5. Preferred

References and videos used in the study:

Thank you!

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Gregory LeMasurier, Alvika Gautam, Zhao Han,
Jacob W. Crandall, and Holly A. Yanco.

Contact: gregory_lemasurier@student.uml.edu

Check out our LBR:

A Generalizable Architecture for Explaining Robot Failures Using Behavior Trees and Large Language Models.
Christian Tagliamonte*, Daniel Maccaline*, Gregory LeMasurier, and Holly A. Yanco.

Stay tuned for new results! (In submission to RO-MAN)

This research has been funded by the Office of Naval Research (N00014-18-1-2503 and N00014-23-1-2744).

Understandability

Possible Cause of Failure	Failure Condition: Screw Bin Empty			Screw Bin Moved			Caddy Out Of Reach		
	Base	Reactive	Proactive	Base	Reactive	Proactive	Base	Reactive	Proactive
An obstacle was blocking the robot from driving to the table							1.67%	14.52%	
The robot hit an obstacle while driving around	1.61%								
There were no screws in the bin on the table	24.19%	37.70%	**63.49%**		1.59%	6.78%	1.67%		
There was no caddy on the table							5.00%	3.23%	
The robot could not detect the screws that were in the screw bin	4.84%	**52.46%**	26.98%		1.59%	8.47%			
The robot could not detect the caddy that was on the table	11.29%		1.59%	12.50%	9.52%		**40.00%**	24.19%	9.38%
The screw bin was moved while the robot was looking for screws	3.23%			**59.38%**	**57.14%**	**72.88%**	3.33%	1.61%	1.56%
The caddy was moved while the robot was looking for it	3.23%			6.25%	7.94%	8.47%	8.33%	4.84%	1.56%
The robot could not reach the screws because they were too far away		1.64%		3.13%	11.11%		1.67%		3.13%
The robot could not place a screw in the caddy because the caddy was too far away						1.69%	33.33%	**38.71%**	**81.25%**
The robot reached for a screw, but missed				10.94%	4.76%				
The robot dropped the screw									
The robot's arm malfunctioned	6.45%							1.61%	
The robot's camera malfunctioned	3.23%	1.64%	1.59%	1.56%			1.67%		
Not sure	**25.81%**	6.56%	4.76%	3.13%		1.69%	1.67%	1.61%	
I did not observe any failures or errors	11.29%								
Other	4.84%		1.59%	3.13%	6.35%		1.67%	9.68%	3.13%
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Influence on Understandability