# Robot Communication Via Motion: Closing the Underwater Human-Robot Interaction Loop

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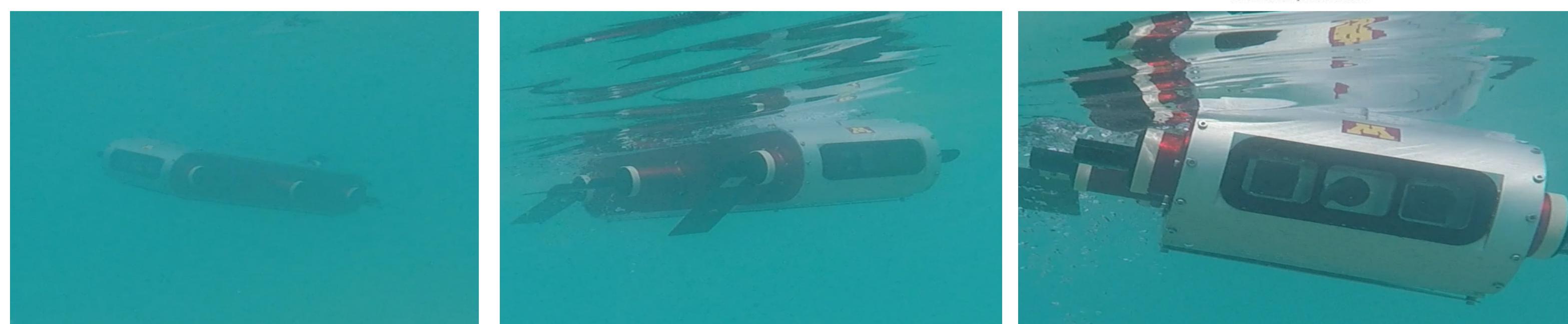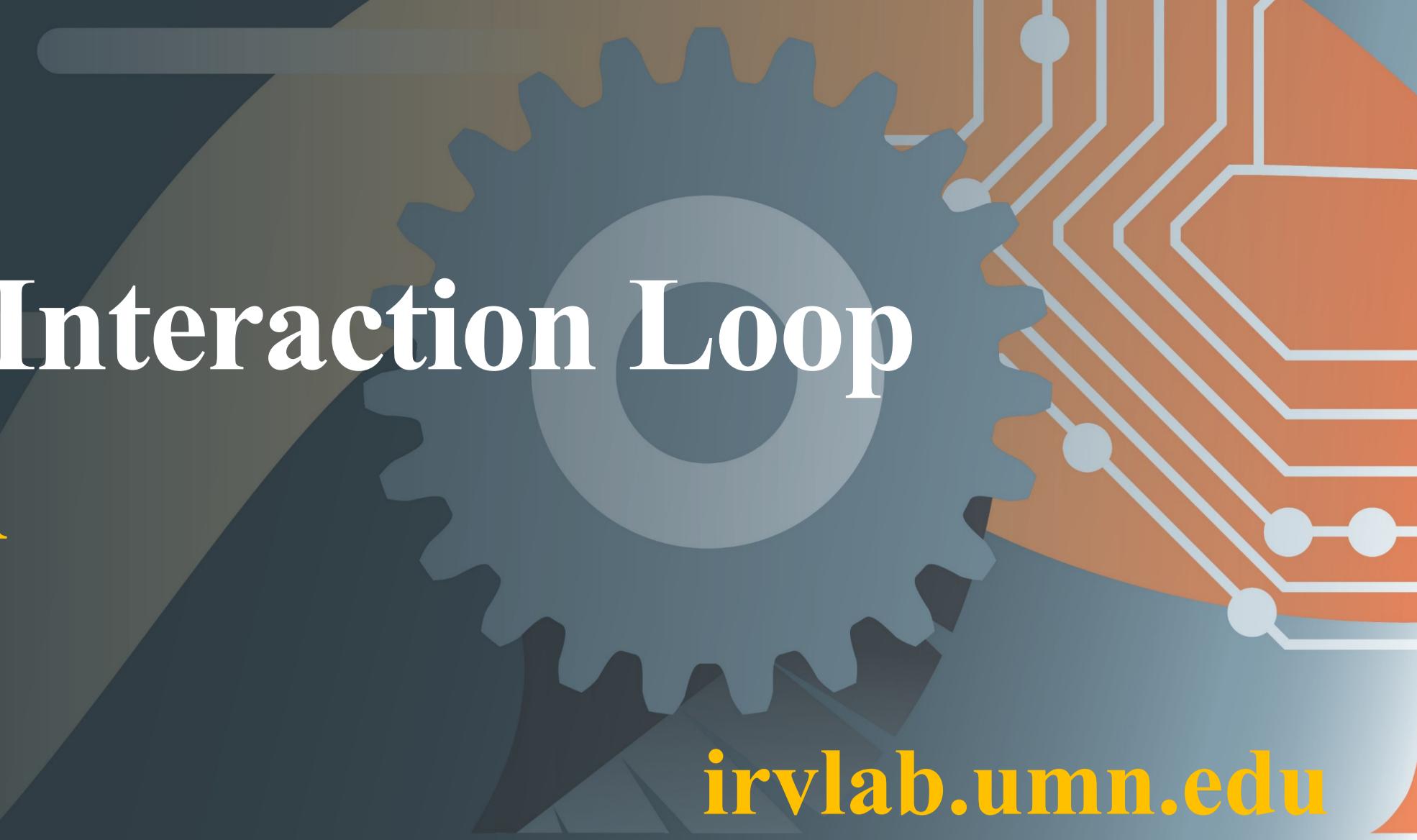
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ICRA 2019 International Conference on Robotics and Automation
May 20-24, 2019 Montreal, Canada

Contributions

- A unique underwater robot-to-human communication system.
- Motion system compared with other relevant systems.
- Groundwork for development of full-loop underwater HRI.

Key Ideas:
- Kinemes - motions associated with distinct meanings.
- Tap into natural human ability to understand motion.
- Communication of information, not emotion.

Motivation

- Underwater human-robot interaction (UHRI):
  - Significant work has been done on human-to-robot communication and two-way systems requiring peripherals.
  - Little work on robot-to-human communication.

Limitations of Current systems:
- Flashing lights are disruptive and difficult to understand.
- Digital displays are typically very small and hard to read.

Methodology

- Created a set of phrases commonly used underwater.
  - Many have human gesture equivalences.
- Created phrases in Kineme and Light Code systems.
- Systems were evaluated against one another in a user study
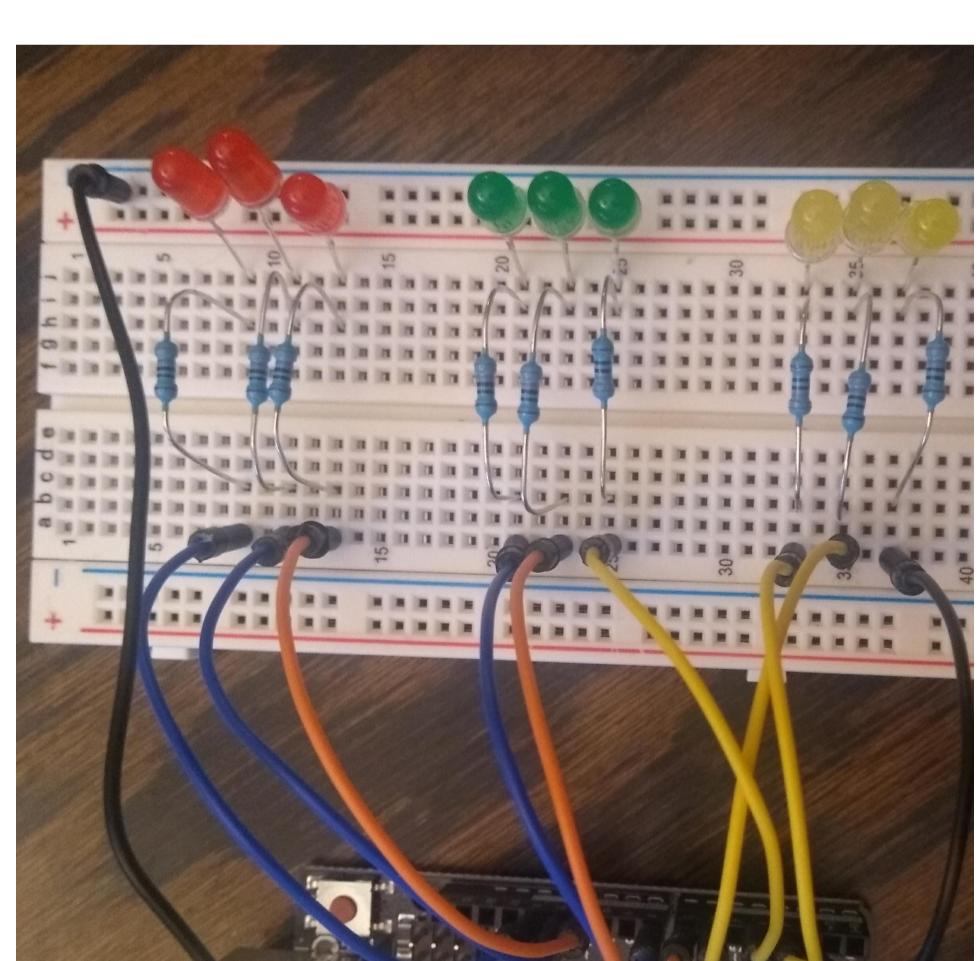
Kineme System:
- Mimic human movements such as head nodding.
- Exaggerate motions to improve readability.
- Exploit and humanoid elements of the robot.
- Implemented using Epic Game's Unreal Engine™.

Light Code System:
- Natural color mappings (Green is good, red is bad).
- Faster blinking means more urgent/important.
- Implemented with Arduino controlled LEDs.

← *Unreal Engine space for animation of kinemes*

System Testbeds

Arduino LED setup for light code system testing. →

Table: Kinemes and Light Codes

Meaning	Kineme	Light Code
No	Yaw robot back and forth	One red light
Follow Me	Beckon with robot "head"	Three blinking yellow lights
Danger	Robot turns side-side fast	Three blinking red lights

Recent sea test of the "No" kineme: Aqua yaws as if shaking its head.

Experimental Setup
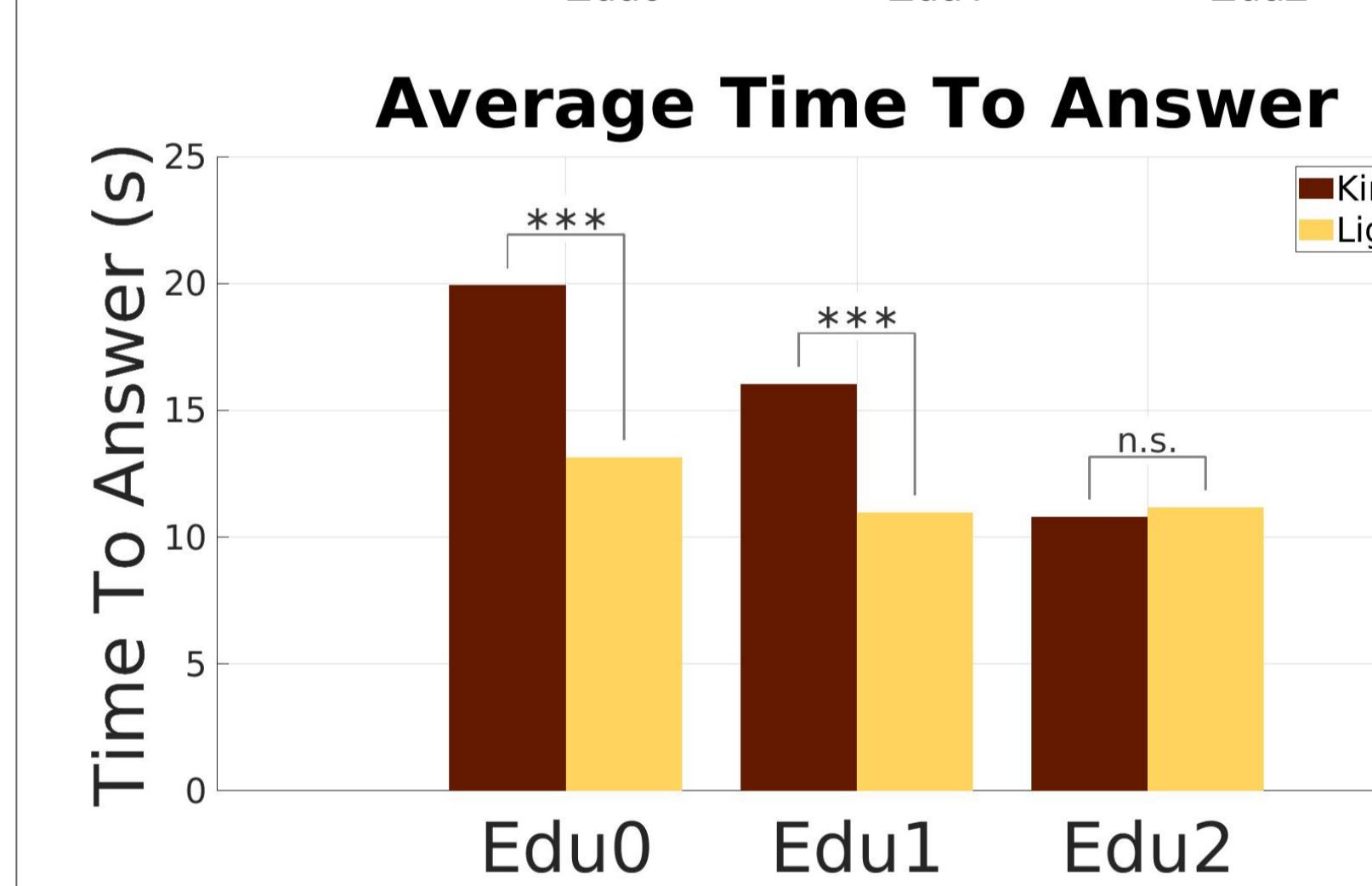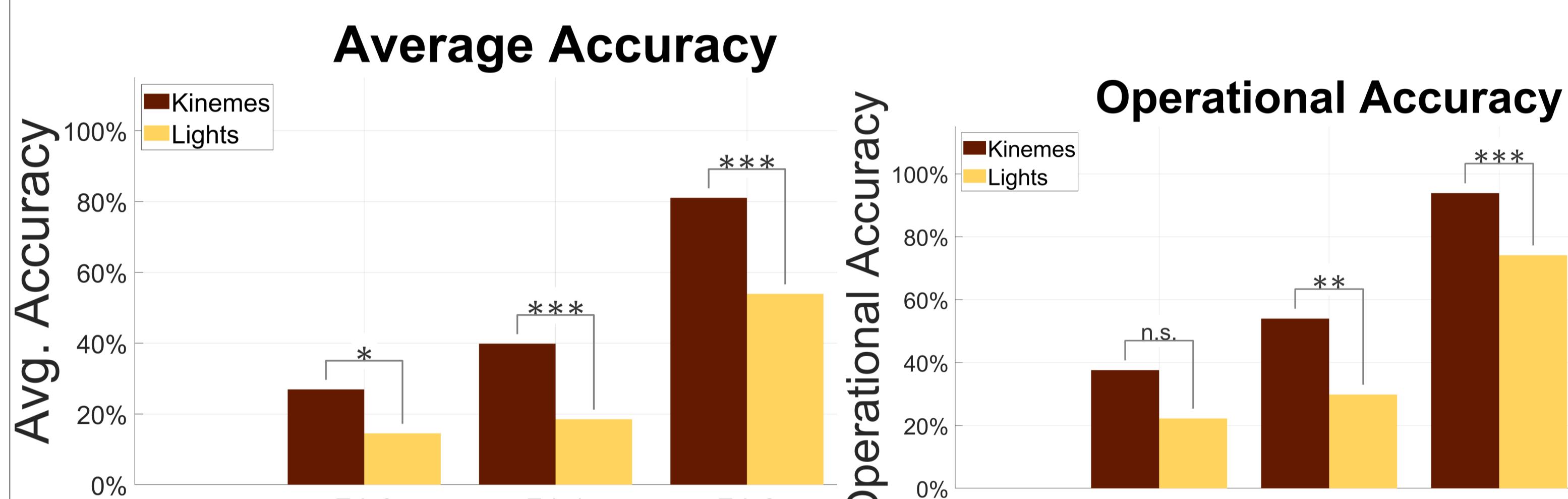
Demographics:
- 24 participants- 16 male, 8 female.
- Mean age of 22 (mostly computer science students).
- Low experience with robots- mean of 1.54 out of 5.

Experiment:
- Participants were shown videos of kinemes and light codes.
- 3 groups of pre-study education.
  - EDU0- Communication vector.
  - EDU1- Communication vector and possible meanings.
  - EDU2- Communication vector, videos with meanings.

Experimental Results

Average Accuracy (Kinemes, Lights)

Operational Accuracy (Kinemes, Lights)
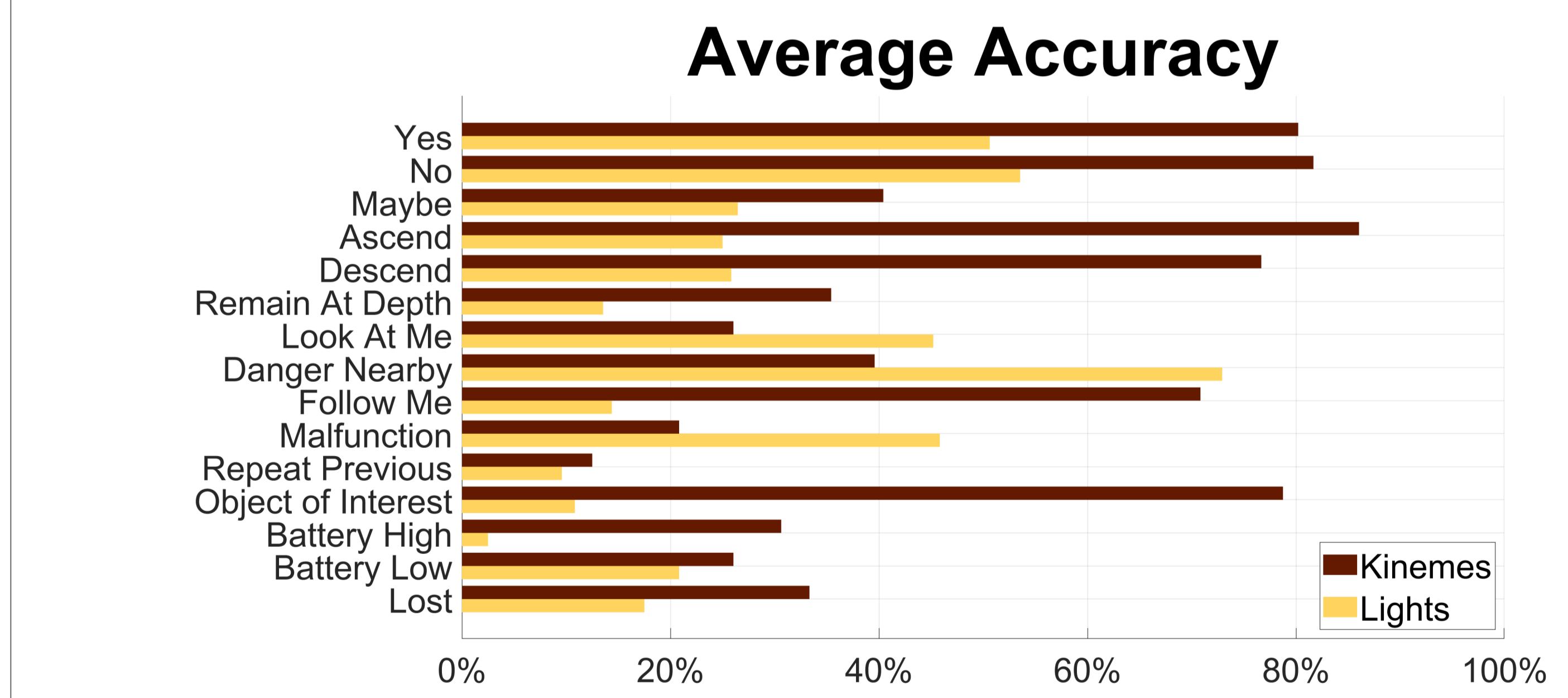
Average Time To Answer (Kinemes, Lights)

Statistical Results
- **n.s.** - Not significant
- ***** - $\alpha <= 0.05$
- ****** - $\alpha <= 0.01$
- ******* - $\alpha <= 0.001$

Order in which systems were shown did not affect accuracy.

Average Accuracy

Yes, No, Maybe, Ascend, Descend, Remain At Depth, Look At Me, Danger Nearby, Follow Me, Malfunction, Repeat Previous, Object of Interest, Battery High, Battery Low, Lost (Kinemes, Lights)

Future Work

- On-robot implementation of kinemes.
- Extension of kinemes to other robots.
- Evaluating using in-person experiments.
- Evaluation of kinemes robustly over orientation and range changes.

Read more!