Understanding Human-Robotic Lawnmower Interaction in Different Contexts

An exploratory study to understand and improve human perception of autonomous mobile robots

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Introduction

What is Human-Robot Interaction? And Why is it important?

Introduction

What is HRI?

Human-Robot Interaction (HRI) covers studies on interactions with robots and how to enhance them. This project focuses on autonomous mobile robots (AMRs), particularly.

Improving HRI

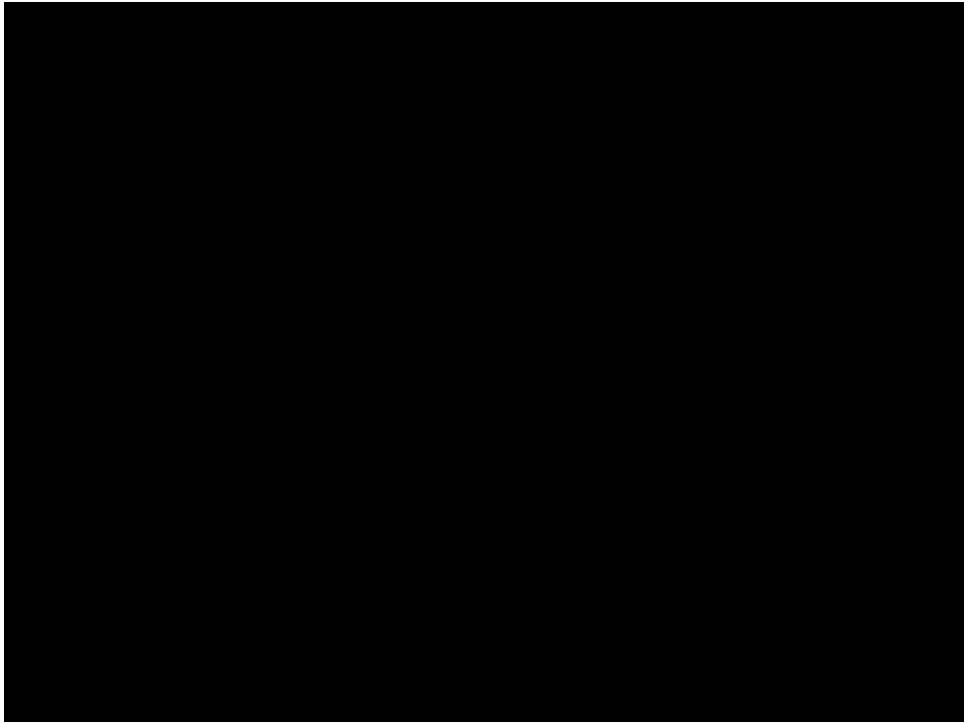
Previous research in HRI establishes that trust is crucial to enhancing human interaction with robots. In this study, we use intent communication (by displaying social behaviours) as a way to build trust.

Intent Communication

The idea is, if these robots exhibit social behaviours that indicate situational awareness (by communicating intent), humans would feel safe, and thus improve human perception.

Why do we care?

- Autonomous mobile robots are increasingly becoming a part of the workforce and other operations.
- While the development in this space has been focused on improving the mechanical efficiency and longevity of the machines, little work has been put into making them "social".
- For an amicable coexistence of robots and humans that share physical space, it is important to improve human perception of robots.
- Improving human-robot interaction will, in turn, enhance the quality of life.



Why do we REALLY care?

Objective of the degree project

Research Question

How will the behaviour of robotics lawnmowers, acting upon the multimodal input received from the environment, be perceived by pedestrians and other humans in the scene?

Hypothesis

Successful communication of intent by a robot could positively influence the perception of trust and safety toward that robot.

Goals

Subgoal 1

Develop viable interactions that are effective, cost-efficient, and make the robot “socially” intelligent.

Subgoal 2

Explore patterns in movement-based and light-based communication to apply to autonomous mobile robots and to translate findings from other domains and test them here to verify cross-domain applicability.

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Background

What do we know about communicative movement and expressive light and the related work?

Pillars of enhancing human-robot interaction

Trust and Safety

Attention and Expressiveness

Intent Communication

Related Work

Autonomous Mobile Robots

Autonomous Vehicles

Autonomous Free-Flyer

Human-Robot Proxemics

Multimodal Intent Communication

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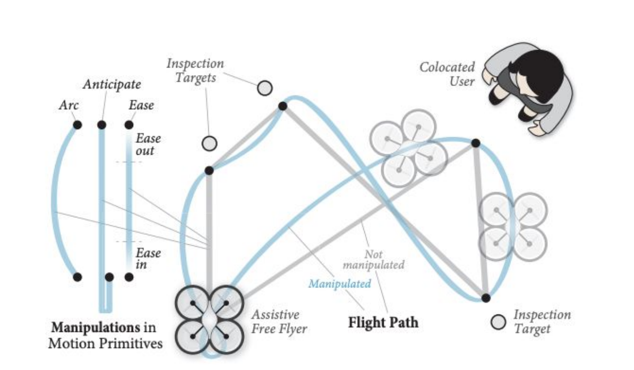

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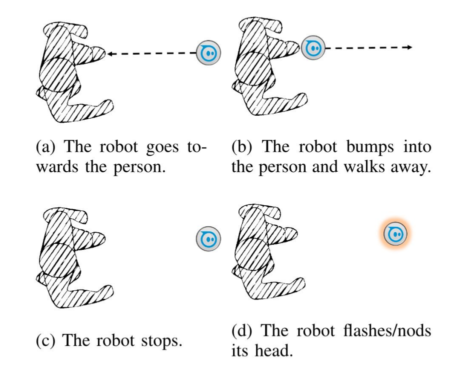

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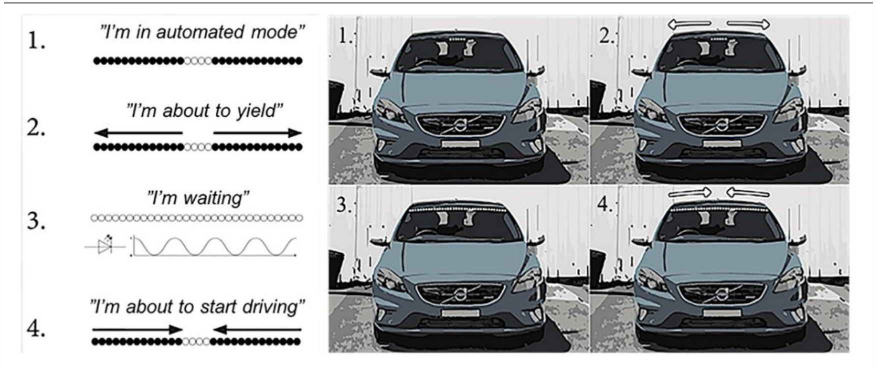

i. D. Szafir, B. Mutlu, and T. Fong, "Communication of intent in assistive free flyers," in Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction, Bielefeld Germany: ACM, Mar. 2014, pp. 358–365. doi: 10.1145/2559636.2559672.
ii. M. Faria, A. Costigliola, P. Alves-Oliveira, and A. Paiva, "Follow me: Communicating intentions with a spherical robot," in 2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), New York, NY, USA: IEEE, Aug. 2016, pp. 664–669. doi: 10.1109/ROMAN.2016.7745189.
iii. A. Habibovic et al., "Communicating Intent of Automated Vehicles to Pedestrians," Front. Psychol., vol. 9, p. 1336, Aug. 2018, doi: 10.3389/fpsyg.2018.01336.

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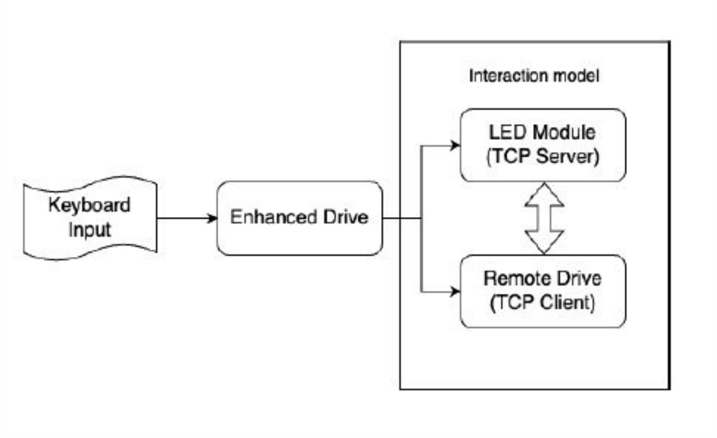
Interaction Design

What did we do?

Modifications

Software

- Build upon existing robot behaviour to incorporate expressive lights.



Hardware

- Polished application of the light strip to ensure a seamless build

Behaviour design

Moving-Facing

The human and the robot are moving toward each other.

Stationary-Facing

The human is standing in place when they observe the robot moving toward them.

Moving-Not-Facing

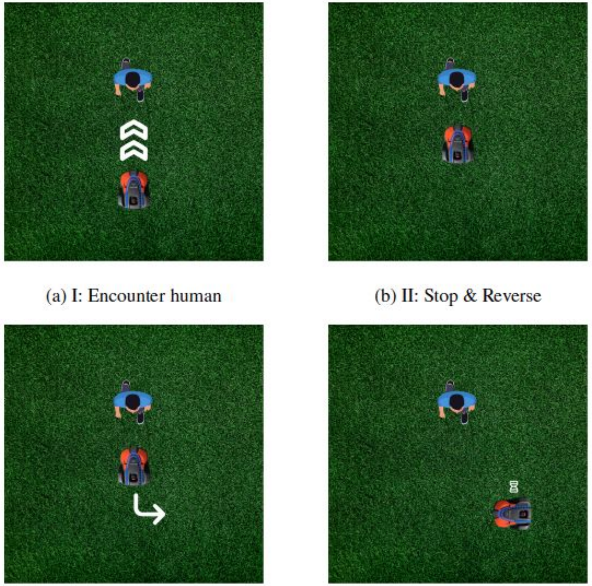
The human is walking in front of the robot.

Stationary-Not-Facing

The human is standing in place and the robot approaches them from behind.

Moving-Facing (yield way)

Derived from the real-world scenario where a person walking through a park might encounter a mower in their way.

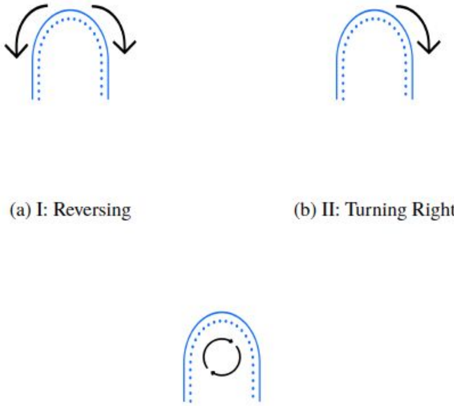


(a) I: Encounter human

(b) II: Stop & Reverse

(c) III: Turn Right

(d) IV: Wait



(a) I: Reversing

(b) II: Turning Right

(c) III: Waiting

Figure 3.5: Light interaction behaviour for yielding way

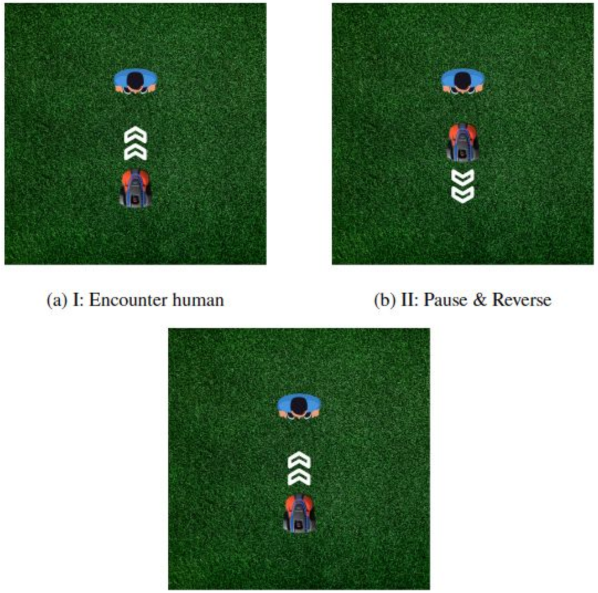
Moving-Not-Facing (slow down)

Extended from the real-world scenario where a person is walking through a park and the mower is right behind them.

(a) I: Encounter human (b) II: Maintain Distance

Stationary-Facing (move away)

The real-life inspiration for this abstraction is when a person is standing in a park and occupying the space that the mower wants to mow.



(a) I: Encounter human

(b) II: Pause & Reverse

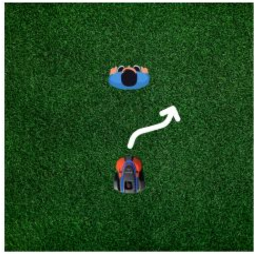
(c) III: Go forward and repeat I

(a) I: Reverse

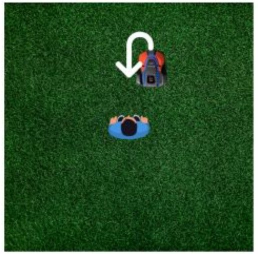
(b) II: Go Forward

Stationary-Not-Facing (manoeuvre + move away)

This abstraction is similar to the one above, except that the mower approaches the human from behind; i.e. the human does not see the mower approaching them.

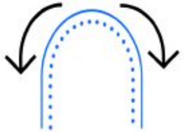


(a) I: Encounter human & manoeuvres around

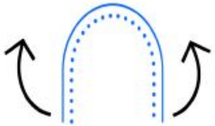


(b) II: Face the human

(c) III: Repeat "Move Away" behaviour



(a) I: Reverse



(b) II: Go Forward

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Methodology

How did we do it?

Research Process

Literature review

We conducted an extensive pre-study that helped us identify research gaps and conclude where we could place the current study

Development

Abstracted real-world scenarios for the mower and developed suitable interaction behaviours for it.

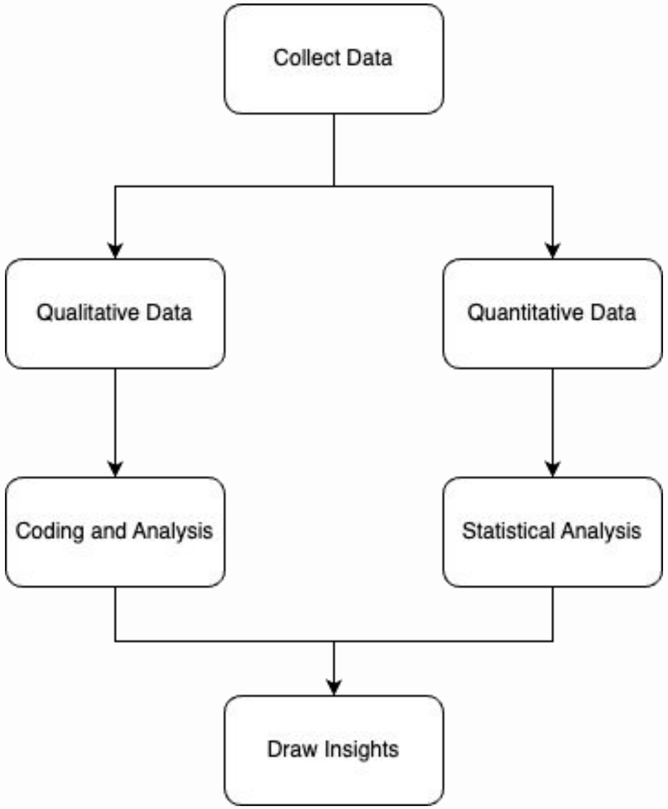
Data Collection and Analysis

Conducted an online-video-study to evaluate the effectiveness and legibility of the developed interaction behaviours.

Data Collection Process

- We developed a survey divided into different blocks that collect a wide range of data, from demographic information to assessment data for the videos.

- Along with the qualitative data, we also collected quantitative data that aimed to assess participants’ safety and trust perception of the robot.



Survey Contents

Demographic Data

- Recruited on an online research platform
- Pre-screened based on approval rating and participation history

Interaction Questionnaire

- Qualitative data
- Describe Mower behaviour
- Mower Intent Check
- Complementary Light behaviour

Safety and Trust Questionnaire

- Quantitative data
- Trust perception due to robot's social behaviours
- Safety perception due to robot's social behaviours

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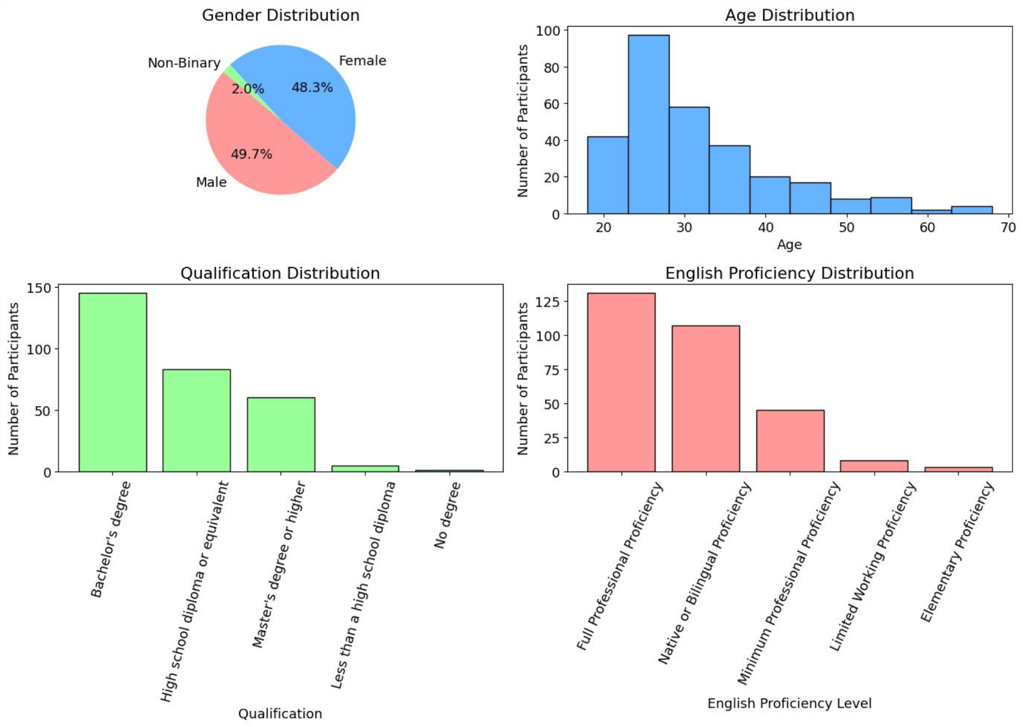
Results and Analysis

What did we find?

Demographic Data

Overall, the dataset is fairly balanced in terms of gender, the age range is broad, the majority of the participants hold at least a Bachelor's degree, and most participants report high proficiency in English.

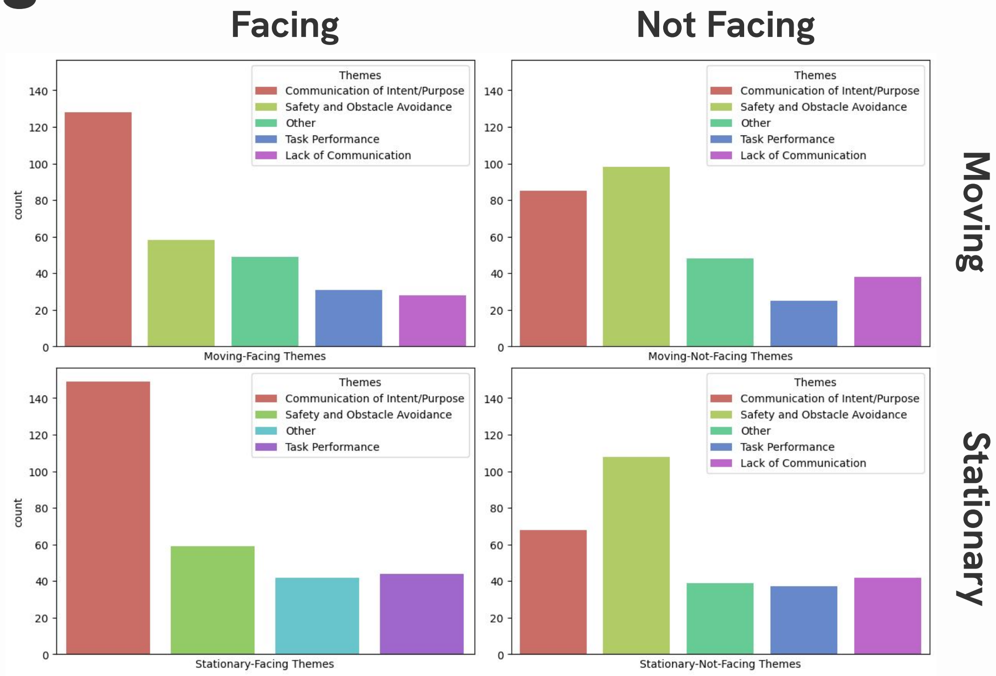


Qualitative Analysis

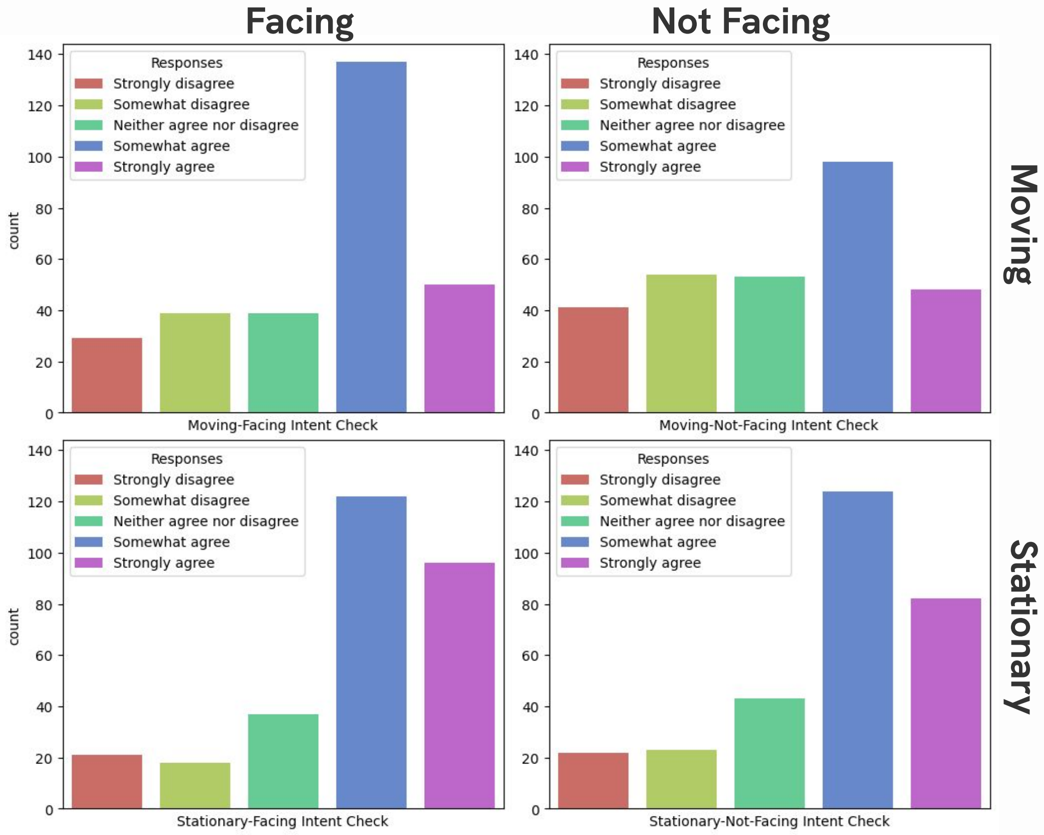
- For each of the interaction behaviours, we ask the participants to **describe the behaviour**, **whether the mower is communicating intent and describe it**, and **if the light behaviour complements the movement behaviour.**

- For the free-text questions, we perform thematic analysis by coding them and classifying them into categories.

- Overall, participants were able to describe the behaviours and identify the mower intent for each scenario.



Do you believe the mower is attempting to communicate a purpose?



Quantitative Analysis

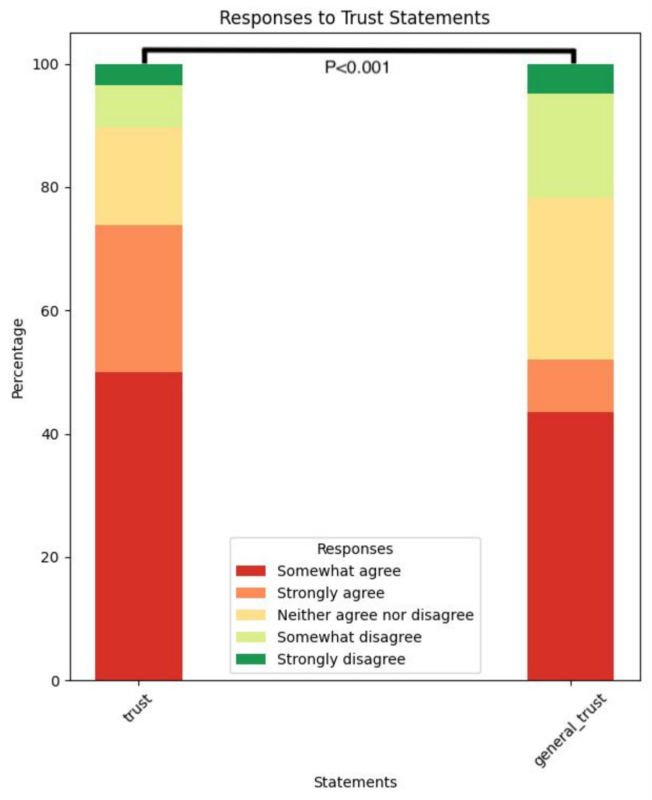
- Apart from free-text responses, we also collected Likert scale data to assess **trust** and **safety** perception.

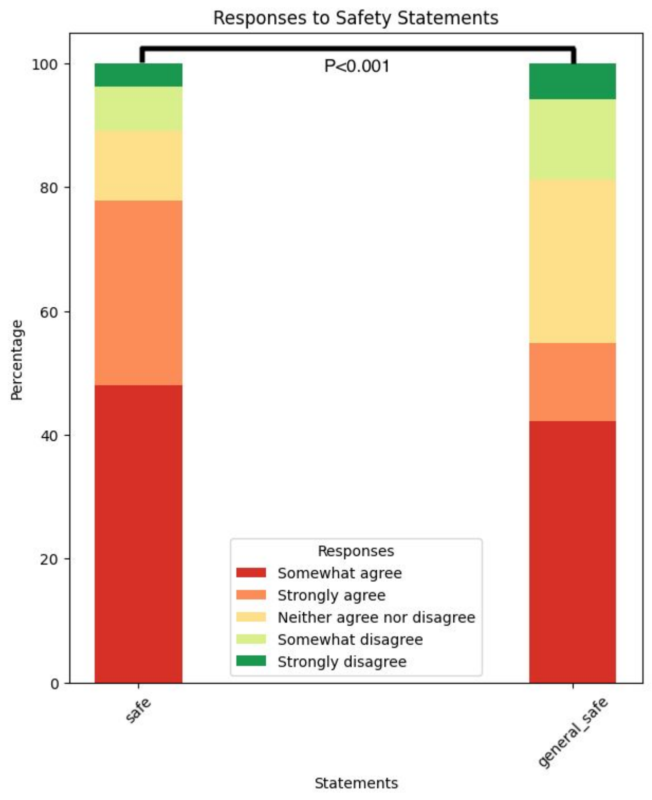
- Furthermore, we analysed the internal reliability of the responses collected pertaining to the robot's social behaviours. We compute the **Cronbach's Alpha (α) = 0.86**

- **Trust**:
  - We asked participants if they trust the robot more because of the social behaviours it exhibited, vs. if they trust robots in general.
  - One-tailed Mann-Whitney-U (**MWU**) test, for the **294** observations, suggests that participants would trust robots who exhibit social behaviours more.

- **Safety**:
  - We asked participants if they would feel safe around the robot more because of the social behaviours it exhibited, vs. if they feel safe around robots in general.
  - One-tailed Mann-Whitney-U (**MWU**) test, for the **294** observations, indicates that participants would feel safer around robots exhibiting social behaviours more.

Responses to Trust and Safety Statements





Impact of Intent Communication

- We segregate the responses based on whether they were **successful** or **not successful** in identifying mower intent, then look at their responses to trust/safety statements.

- **Trust**:
  - Participants that could identify mower intent, based on 221 responses and another one-tailed MWU test, indicated that they would trust a robot displaying social behaviours more; while the same could not be concluded with participants who did not identify mower intent.
- **Safety**:
  - There wasn’t a statistically significant difference between participants who could identify mower intent and those who couldn’t, both groups indicated that they would feel more safe around the robot showing social behaviours.

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Conclusion and Future Work

Where do we go from here?

Discussion

Legibility and Effectiveness

Leveraging existing mental models

Different importance of intent communication

Agency Attribution

Conclusion and Future Work

- Through the experiments conducted here, we validated the claim that people have a high tendency to trust and feel safe around a robot that shows social behaviours. Be it acknowledging human presence, or reacting to the human's action in the scene.

- Another by-product of this project is the **repository of interaction behaviours** mapped to four distinct real-world scenarios, this establishes a basis for future work where other scenarios could be explored.

- Apart from this, one could also explore other modalities for the interaction behaviours, some works make use of **extra linguistic expression** cues to communicate a robot's internal state. Besides this, other forms of modalities such as **haptics**, **projection**, **screens**, **audio**.

- To further improve context-aware navigational capabilities, the interaction behaviours of the AMRs could be coupled with Deep Reinforcement learning (DRL) approaches

Thank You!

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