Comparing efficiency and comfort level of expressive behaviors, in human-robot interactions, playing the children's game, Red Light, Green Light

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Abstract

Robots, when placed in the game setting, need to maintain effective communication with the users in order to achieve good human-robot interaction and deliver a positive user experience. For this reason, in this project we investigate different expressive behaviors of the robot, measuring and comparing their performance in the game setting. We approach this problem by designing a robot to perform a game similar to "Red Light, Green Light", where the robot will serve as the person standing in the front, giving the indication to participants when they can move and cannot. The robot will detect the movements of the participants and use various expressive behaviors to inform participants who move and lose the game. Compared to some prior work that also investigates different channels' effect on transparency, like the work from Wang et. al[8], our work is different because firstly we are investigating three different expressive behaviors– voice, lightring and movement, and also our study is in a multiplayer game setting. Our robot uses a deliberate model for control – it will use an RGB camera as input data and perform movement detection, then it will perform different expressive behaviors to inform participants if they are eliminated and lose the game. We evaluate the work by giving post-study surveys to our participants and performing analyses on the results. Our key finding is that sounds give the best result in both efficiency and user preference, while lightring give the worst performance. We believe our results will be useful for HRI as it explores user preferences of how robots communicate with users in the game.

1. Introduction

The problem we are trying to investigate is to compare three different robot's expressive behaviors to communicate with the user - movement, lightring and sounds - and to see which one works better. The motivation of this project is that signals or cues are important for how robots communicate with the users, and find a better way to bring efficiency and a better user experience.

Work from Taylor, A. and Riek, L.D.[6] finds a new method that enables robots to detect and track groups of people from an ego-centric perspective, which is similar to the method we are using in our robot design which is to track the motion of a group of people. Paper from Wang et. al[8] performed an investigation on transparency and anthropomorphism in the voice channel and visual channel of the robot. This paper motivates our research questions as it demonstrates the significance of the careful implementation of transparency methods. Similar to this paper, our work also investigates the different channels of robot's communication, but we investigate through three different ways– voice, lightring and movement and also in a multiplayer game setting, which is different from this paper.

Our approach is to design a robot to perform the game Red Light, Green Light. The robot will first have its back towards the participants, and they can move towards the robot. When the robot turns around, participants cannot move, otherwise, they fail and are eliminated. The robot will detect the movements of participants and use different expressive behavior to inform participants they lose the game. We implemented ROS nodes, movement detection and navigation for the robot behavior. The evaluation of efficiency, accuracy, and user preferences are through a post-study survey that is distributed to the participants. We performed anal-

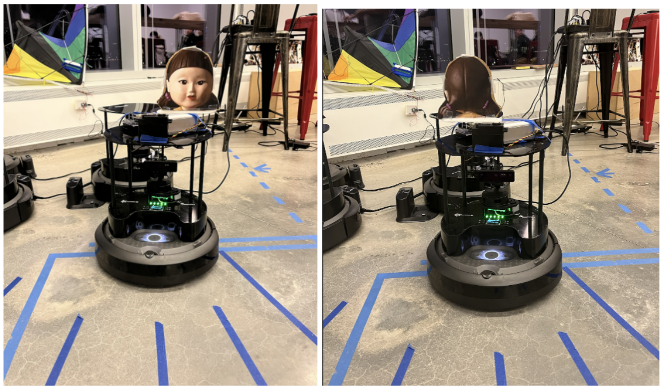

Figure 1: Robot's appearance

yses on the results and found out that sound gives the best result in terms of efficiency and user preference. The study is experimental.

2. Related Work

Taylor, A. and Riek, L.D.[6] paper introduces the Robot-Centric Group Detection and Tracking System (RE-GROUP), a new method that enables robots to detect and track groups of people from an ego-centric perspective using a crowd-aware, tracking-by-detection approach. This paper is related to our paper as tracking multiple people will be in use of our own study, as in our game, the robot needs to detect and track 2-3 participants. For this reason, we can take the result of this paper as a reference. Our paper is different from this paper as we are using this technique in a study as a part of our game.

Wang et al.,[8] investigated the characteristics of transparency and anthropomorphism in robotic dual-channel communication, encompassing the voice channel and the visual channel. Transparency can be defined as a way of establishing shared intentions and awareness between human and robotic systems. The key features of transparency in human–robot systems are understanding the robot's purpose, analyzing their actions, and receiving information from them about decision-making and environment-aware analysis processes. This paper is related to our study as in our study, we are also exploring the transparency in HRI, using various visual and voice clues to see which achieve the best results in terms of communication and users' experience.

3. Method

3.1. Participants

In this study, we expect to recruit 6 groups of participants with each group having 5 participants to perform a between-subject experiment where each group will experience all cues in different orders. However, in practice, we are only able to recruit 10 participants and divide them into two groups (5 participants per group) and perform an MVP-level experiment instead. We recruited our participants by using the snowball method. And the demographic data for age is that the mean age is **22.9** and the standard deviation is **1.37**. The gender breakdown by **9:1** where 9 males and 1 female are in our experiment. For the level of experience with robots, our mean familiarity value is **2.8** and the standard deviation is **0.67**.

3.2. Robot Behavior Design

Since we are going to replicate the Red Light, Green Light game with our robot, we will define our robot to have the following behaviors:

- Counting Down to indicate the start of the game
- When the game starts, our robot will turn its face(note only the face instead of the whole robot) backward to the participants.
- After a random time period, the robot will turn its face toward the participants.
- At this phase, the robot will start to detect human movement, and if there is any movement, the robot will identify that person and indicate the individual that has been eliminated.

With the above pre-defined behavior, we believe that we are able to replicate the game of Red Light, Green Light.

In order to perfectly record the human movement and their spatial location in the 3D world, our assumption is that the robot should stay stationary and all participants should be separated by a significant distance like 30 centimeters minimum (Figure 2 Shows our lane settings). All participants should stay in their lane while playing the game. All the above assumptions are made to ensure that we will have a better effect on human movement detection.

Our state machine is defined by Figure 3 . Our state machine is mainly a replication of the previous robot's behavior in a more precious way of representation. In addition, the transition between the counting-down node and the turn-backward node is 5 seconds, and the transition between the turn-backward and turn-forward is a random number generated during runtime to facilitate a more immersive game experience.

We choose to use a top-down approach (Deliberate model) to control our robot. In this way, by using our state machine, we can schedule our RGB camera and Move Detection node to sense the surroundings. Once movement is detected, we can instruct the node to call the Calling Out node to process other predetermined actions. To summarize, our system is utilizing the following sensors, actions, and motors to perform the task:

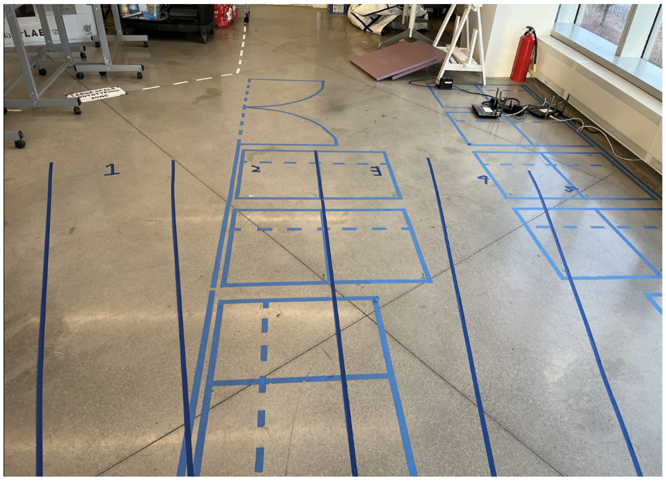

Figure 2: Lane Setting

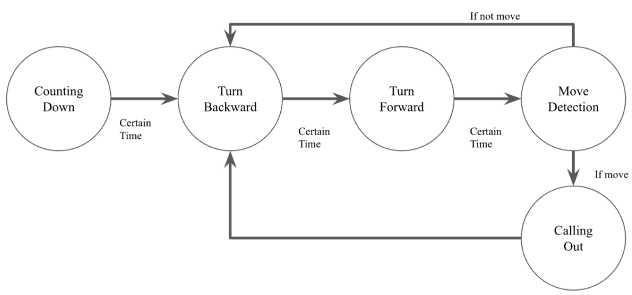

Figure 3: State Machine

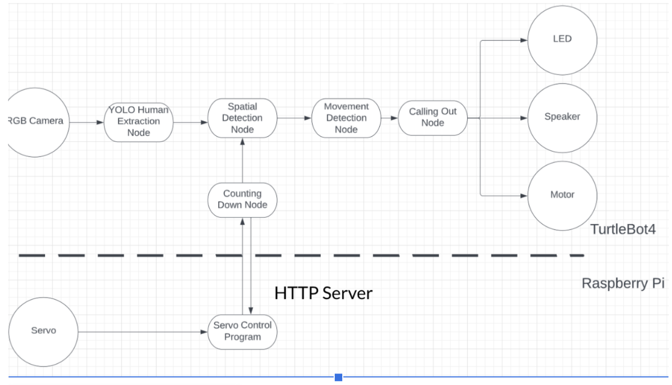

Figure 4: ROS Node Diagram

- RGB Camera
- OAK-D Computing Unit[2]
- Motor
- Led Light-ring
- Speaker from Laptop

In terms of our ROS system implementation, the below diagram 4 illustrates what is happening within our system.

Here, we launch two nodes from the depth-ai[1] to enable the ability of YoLo Human Extraction and Spatial distance estimation. Upon that point, we will have a set of data describing the detected objects from the RGB Camera with a bounding box and spatial location. Alongside with the above-mentioned data, we then trigger our movement detection node and determine if any figure is moved beyond a threshold. After that, if there is any movement detected, the movement detection node will send a signal to the calling out node and indicate which type (LED, Speaker, or Motor) of the cue will be processed. Apart from that, we also have a separate Raspberry Pi that controls our robot's appearance interaction. And in order to sync the behavior between the robot and Raspberry Pi, we set up an HTTP server to connect them together.

The major algorithms we are using here are the YoLov4 object detection and object tracking with depth-ai[1]. Their input is simply an image frame from the RGB camera and outputs the corresponding detected results with the bounding box, spatial location, and object category. Essentially, the above algorithms utilize Deep Learning, Kalman filter, and other machine learning techniques to accomplish.

Our major technical components should be human extraction and spatial position estimation and the ability to detect if one individual has movement. The former components could be achieved by the above algorithms we discussed. For the latter one, we implemented MVP algorithms to detect if one person is moving based on their initial position. A pseudo-code of that shows at algorithms1.

Algorithm 1 Human Movement Detection

Sort Position Array X based on y distance
Take previous frame sorted Position Array as Y
while $i \neq 5$ **do**
    if abs(X[i].x - Y[i].x) $\geq$ THRESHOLD **then**
        Return i is moving
    end if
    $i += 1$
end while
Return Not moving

3.3. Study Design

For this study, we will perform a between-subjects experiment and each group in our experiment will experience all of our cues mentioned above in different orders. In this way, we can try our best to eliminate the bias of order.

For this experiment, our goal is to see if different cues will make users feel comfortable in the gameplay and if dif-

	Comfort level	Efficiency of Sound	Efficiency of LEF	Efficiency of Movement	Appearance of the robot	Recognization level of signal
GroupA(LED-Sound-Move)						
GroupB(Sound-Led-Move)						

Figure 5: Factorial Design Table

ferent cues will help users understand the gameplay. Therefore, we believe by performing a human-focused study, we will get a better understanding of what is going on.

In terms of the sampling method, we were using snowball sampling to recruit our participants on campus. Since we are approaching the final week of our semester, it will be hard for us to do something like stratified sampling. Snowball sampling will be the most effective way to recruit participants by asking people to find their friends and friends' friends to join the experiment.

With the above discussion, we believe that our factorial table will look like Figure 5

3.4. Study Task

As for the study details, after we get the participants' consent, we will lead participants to the location of our experiment. Randomly assign them to a lane numbered from 1 to 5. Then we will let each group of participants experience all cues (lighting, sound, and movement) we mentioned previously while they are playing our game. During the game, we will observe the participants who get eliminated and determine if they can correctly understood the cue that they recieved.. However, in our original design, we also wanted to measure different cues and their response time by taking a video and performing a quantitative analysis afterward. Due to the limited time we have, we have to drop this idea. Finally, after the game is done with the three cues, we will distribute the questionnaire. (Post-Study Surveys) about the comfortability of the game and the efficiency of getting signals from the robot. We will perform a quantitative and qualitative analysis based on the questionnaire.

3.5. Data Collection

In this study, our data is mainly collected by the post-study questionnaire with some open-ended questions afterwards to asses their comfertability level and their experience with the game's efficiency. From our original plan, we did want to also record a video during the game play and estimate how long each individual will take to get the signal.

4. Evaluation

4.1. Experimental Metrics

For this study, we are focusing on the human-focused study, and the study was conducted in a realistic context, allowing the participants to engage in actual interactions with the robot that was equipped with various cues, enabling us to track changes in the participants' responses.

We will evaluate the user's experience and comfortability of the game by using a post-study questionnaire. The questionnaire includes inquiries about the user's comfortability with the whole process of the game; the rate of the efficiency of each cue; recognizability of each cue (LED light, movement, auditory cue). The questionnaire also consists of questions regarding the user's personal information such as gender and birth year.

The reason that we take comfortability as an important metric is because it's a key factor in determining the users' attitude toward the robot. The collaboration quality between humans and robots has been largely improved by comfortability[9]. Low comfortability will lead to a bad user experience and inaccurate experiment results. Based on this concern, the participants were asked to rate their comfort with the game.

Nonverbal communication (light and movement cues) is an unspoken form of dialogue that allows people to understand each other. Robots' effective utilization of verbal and nonverbal communication is significant for connecting with humans as it provides a more intuitive way of interacting with them[5]. Because of the importance of recognition of cues and the goal of this experiment, the participants were asked to answer how recognizable each cue was. For LED light cue, the participants will understand if they have been eliminated if the n time blinking of the light is equal to the number of the lane that they are in. For movement cues, the robot will move toward the participants to indicate that they will be eliminated. Finally, the auditory sound cues will notify the participants who will be eliminated from the game by saying the number lane they are in. These three different cues will be compared against each other in the effort to discover which method is the most effective in this games setting.

After recognizing the cues that were sent from the robot, the third metric that we are taking into consideration is the efficiency of the cues with the robot from the participants' perspective. The high efficiency of the game will make the participants react during the switches between the Red Light and Green Light in lower latency, which yields more accurate results for our goal.

4.2. Data Analysis

After the experiments have been conducted, we collected the results from both groups through the post-study questionnaire. Each response was allocated to a numerical value on a scale of 1-5 for easier computation and comparison. We used Microsoft Excel to create bar graphs that show how each group responded to the different cues. We also used descriptive qualitative analysis to come up with our results from this experiment. The frequency of responses in each category was calculated by using absolute numbers and percentages for an easier interpretation of the data. To further analyze the results of this experiment, we compared the results between both groups. Using descriptive data analysis, we observed that while some participants found lighting to be the most recognizable primary signal, others found sound cues to be more recognizable. Similarly, a few participants reported that movement cues were not as efficient but still manageable; for other participants, it was one of the most efficient ways for them to understand if they have been eliminated or not. In terms of comfortability with the robot and game, we observed that participants from both groups felt comfortable playing with the robot, suggesting that the anthropomorphism used in this setup was successful in gaining participants' trust. We also compared if there were any differences between genders in terms of participants' understanding and comfortability towards the game which resulted in no significant changes between genders. Overall, sound gave the best results for both user preference and efficiency.

Altogether, this project taught us valuable lessons about using nonverbal cues (LED lights, movement) with robots for HRI as well as how to optimize experiment design including participant recruitment, experiment techniques, and data analysis for an improved user experience.

5. Results

The overall goal of this project is to conduct the game of Red Light, Green Light utilizing the Turtlebot 4 to detect movement and notify participants if they are eliminated from the game through different cues and observe their behavior. We received results that further informed how we thought of our experiment as a whole. Due to the nature of this project, the experimentation results are predominantly qualitative results. The crux of our experiment was to see how efficiently the different cues of light, movement, and sound would communicate to the participants of the game, and then extract their comfortability and attitude towards the robot. The robot that we created prompts an engagement that has common features with humans to get optimal results from the experimentation. Creating a humanoid-like robot implies modeling how the engagement will be conducted is of the utmost importance. Obtaining results from the robot interacting with other humans without any special training will determine how this study can be applied to other HRI engagement studies[4].

The blinking LED light cue in our experiment yielded mixed results because in our first group of participants, the individuals playing the game were confused with how the LED light would notify them if they were eliminated from the game. We originally made the robot rotate and point towards the participant that was to be eliminated, and the LED light would blink. This resulted in confusion and poorer results for our first batch of participants. For our second group of participants, we received better results because now the user would know if they were eliminated because the LED light would blink an n amount of times which would correspond to which number lane the eliminated participant was in. Overall, three participants found it very inefficient, one found it inefficient, two felt neutral about the efficiency, three felt it was efficient, and one found it very efficient. (Refer to Figure 6.)

The movement cue of this experiment also yielded mixed results. This cue took the longest to perform, but also received the biggest response from the participants. The overall consensus was that they found it to be scary, but in a comedic way. This was most likely due to them feeling comfortable and trusting to our team and the robot that was performing the actions. For both groups, they were usually able to understand whether they were out or not due to the robot moving towards them. This cue proved to be more difficult as the participants moved closer towards the robot because less space was allocated to indicate whether a participant was eliminated. The overall results for the movement cue was that one person found it very inefficient, two people found it inefficient, three participants felt neutral about the efficiency, two participants found it efficient, and two participants found it very efficient. (Refer to Figure 6.)

The auditory noise cue was our most successful way to indicate if a participant was eliminated from the game. Participants from both groups had no problem understanding the robot when it would say the number of the lane that the participant was in to indicate that they are eliminated; it also garnered a comedic response from the participants, resulting in all of them laughing. Overall, for the sound cue, one participant found it inefficient, one felt neutral about the efficiency, two participants found it to be efficient and six participants found it to be very efficient. (Refer to Figure 6.)

In the study, understanding whether the signal is recognizable was a very important aspect of this project. Most participants claimed that the signals that they received were very recognizable, which was 70%. The other participants had different results, which was that 10% found the signal to be recognizable, 10% felt neutral about the recognition of the signal, and then 10% found the signal to be very unrecognizable. (Refer to Figure 8.) This gives us confidence to try out different cues in future work to push the boundaries of how far we can communicate using different cues.

An aspect that surprised us was that when conducting the game, the participants were not apprehensive about playing and were content with taking instructions from the robot. The participants had no reservations in listening to the robots commands and we're happy to take part in the experiment. Another aspect that surprised us was how much of a response we got when the robot would move towards the individual in the movement cue. This can be because of the appearance of the robot being a creepy doll head that rotates 180° through the servo motor that has the perception of “looking at you” . The auditory response from the participants, such as ” oh, that’s terrifying ” and “that’s creepy” informs us in a large way how we would conduct this experiment in a different environment. The anthropomorphism of the robot played a key role in understanding the compatibility of the participants.[8]

The understanding of the participants and groups that took part in this experiment were essential in deriving the best results. We believe there was bias in this study because group members were all members of the Cornell Tech community. This most likely made each participant feel more comfortable and safe when participating. The presence of a familiar group base rather than an individual base created higher levels of group identification and trust towards their group and robot.[3] This can be shown in Figure 7 when observing the comfort level of the game two participants felt uncomfortable, one felt neutral about the comfortability, four felt comfortable, and finally three felt very comfortable. We also did not change the amount of participants to test whether there was a linear relationship between the number of participants and comfort level they experience due to time constraints of the project.

We were surprised that the proximity from the robot to where the participants would start the game to the end had no observable difference in their comfort level. Through qualitative results we observe the participants were just as content with being a few meters away from the robot or being extremely close to the robot. Additionally, time between the cue being output by the robot and the participant understanding the cue, we discovered, was negligible because for each of the participants they understood the signal right away and left the game accordingly.

What we would’ve done differently if we were to do more experiments in the future is to use a larger space because when the participants got closer to the end goal, which was to touch the robot to win the game, the space between them got very small, and the game felt condensed. Hopefully in the future, participants can actually play this game and run rather than fast walk. Another aspect we would do differently would be the participants we would gather. To our knowledge, all of the participants were members of the Cornell Tech community. In the future, we would love to recruit individuals that were more non-partial that we’re outside of this institution.

We measured the success of this project by observing if the individuals can have an enjoyable, understandable, and seamless experience when being informed by the three different cues that we showed while playing the game of Red Light, Green Light. Through the experiments that we ran, the robot was successful in conducting the game of Red Light, Green Light with all three of its different cues.

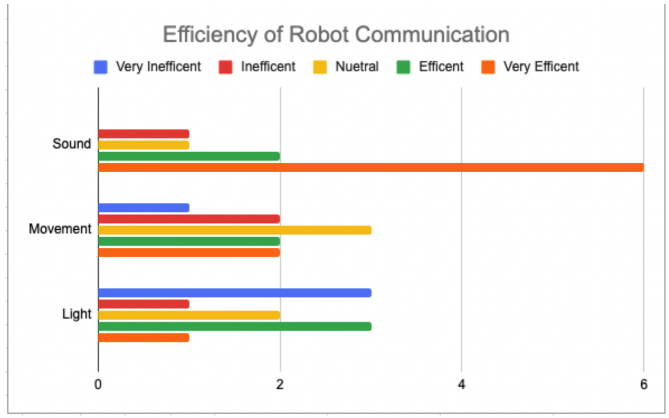

Figure 6: Communication Efficiency

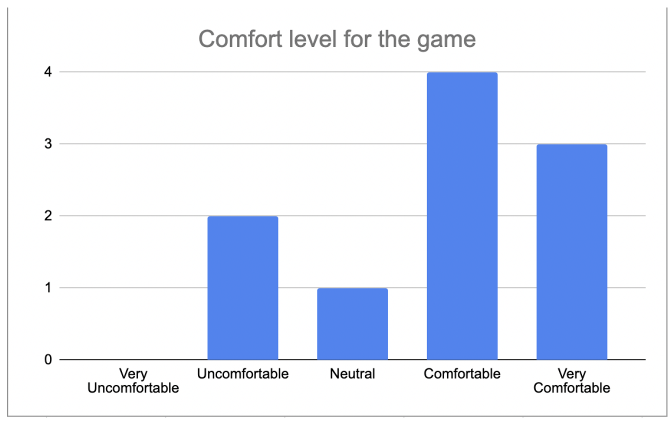

Figure 7: Comfort Level

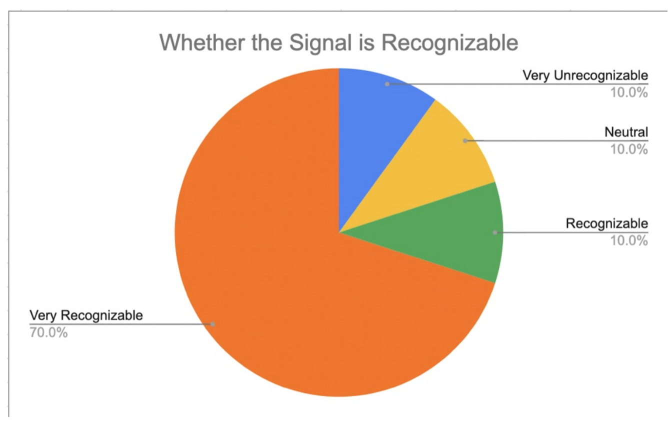

Figure 8: Recognizable Level

6. Discussion & Future Work

The goal of our study was to see the communication between our robot and the participants in our game of Red

Light, Green Light. We wanted to see if the communication methods of auditory noise, blinking LED light, and movement cues from the robot were effective in conducting the game and provided a comfortable environment for the participants.

In the space of recognizing engagement, Charles and Brett describe the importance that different types of engagement should be malleable and be applicable to most engagement processes.[4] Through this thought process, we wanted to test which cues from our humanoid-like robot would be most effective in supplying our participants with information about their position in our game. This also compliments the work of Jianmin and Yujia in the space of anthropomorphic attribute effects on humans to robot interactions. Anthropomorphic characteristics can affect how individuals or groups of people react to instructions from the robot individuals.[8] This was important to keep in mind because of our robot's appearance, and the participants' willingness to play the game. In the space of group-based emotions, Filippo and Francisco describe HRI group interactions being contingent on group trust, identification, and likeability. [3] These aspects were all supported by our experiments and taken into account when conducting them.

The overall results from this study were that the three cues of light, noise, and movement were all effective tools in informing participants if they were eliminated from our game. The degree to which they were successful varied with the auditory sound cue, being superior to light and movement cues. Participants were not apprehensive to play the game and listen to the robots instructions. In fact, we believe through qualitative analysis, that they were happy to do so. Another interesting result of this study was that the attitude the participants had towards the robot did not observably change in regards to Hall's four proximate zones[7].

The participants were mostly comfortable with participating in the game and experienced observable enjoyment. In the future, the goal would be to do this experiment on a larger scale so we could get more quantitative data with less bias. The way we would like to do this is recruit individuals outside of Cornell Tech to participate in playing the game, Red Light, Green Light with our robot. In conjunction with this, we want to have a larger space where we could play this game to see if that changes the overall response to the robot and observe if the proxemics change the overall scope of the experiment. In conjunction with this, we would also want the robot to be autonomous, not being controlled by a Wizard of Oz technician. This would mean that the robot would be able to initiate cues by itself which would have different implications when it would instruct the participants.

Some extensions that will be interesting to see in this project would be the robot taking a different form. Maybe instead of the Turtlebot 4, this would be a fully functioning, robotic doll that would be able to have human-like qualities. This would consist of mouth movement when speaking, turning forward and back, and walking mechanics that would allow the robot to walk with limbs.

The limitations in our study were prominent when we did the analysis of our results. We wanted to do a more quantitative and statistical approach to how people reacted to the robot. Due to time constraints, and the amount of people we were able to get to participate in our experiment, we had to do qualitative analysis and validation of our Red Light, Green Light game that way. The sample size was only 10 so in the future we would like to have somewhere around 80 to 100 individuals to truly capture the communication cue aspect of our study.

A lesson that we learned was that we should've explored different spaces to conduct this experiment that were more expansive and didn't constrict us like our experiments did. Instead of a few meters we would want much more room, so individuals are able to run rather than speed walk. We also learned that experiments are very different theoretically than in practice. We learned this during our first attempt at experimenting with participants. When we attempted to communicate with the participants with the LED light the first time, it did not work because of the spatial boundaries and overall confusion of participants. This informed us that we needed to try a different method of informing the participants with the LED light, which helped us switch to a blinking format that corresponded to the number lane the participants were in.

I believe this study can have positive impacts in the field of HRI, because it shows that individuals can be efficiently instructed by a robot while still having fun participating and being comfortable in a gamified setting. This study also shows a strong case for how different cues can affect the efficiency and comfortability of HRI, which encourages the exploration of using more cues in group settings, and going more in-depth to highly effective cues such as sound.

7. Team Member Contributions

7.1. Technical Components

Patrick Mazza - Creating and the Raspberry Pi servo motor head attachment.

Wenhe Li - Created and implemented all ROS nodes mentioned in the report; Built up the communication code between Raspberry Pi and Turtlebot4.

Yifu Liu - Created and tested the state machine of the robot.

Ka Wing Lui - Overall game and robot design, perform experiments and gather results

7.2. Writing Components

Patrick Mazza - Results, Future Work and Discussion, Consent and Demographic form, Study Survey, and Study Script

Wenhe Li - Setting up Overleaf Project, write up Method section, manage bibliography

Yifu Liu - Evaluation of the report. Taking and uploading videos of the game.

Ka Wing Lui - Abstract, Introduction and Related Work part of the report, Consent and Demographic survey, Post-study survey, Result data visualization

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A. Appendix

A.1. Video Demonstrations

Video Link

A.2. Consent & Demographic Form

Consent and demographic form that acquires signature, gender identity, year they were born, and comfertbility with robots.

Red Light, Green Light HRI FInal Project

Consent and Demographic Survey

Your Signature and Consent

Do you agree to participate? _______

_______________________________________ _____________

Subject's signature Date

Please answer the following questions.
1. What is your gender identity?
Female
Male
Non-binary
Prefer not to say
Other

2. What year were you born? ___________

3. How comfortable are you with robots in general (Choose one)?
Very Uncomfortable
Uncomfortable
Neutral
Comfortable
Very Comfortable

PARTICIPANT # ___________

Figure 9: Consent and Demographic Form

A.3. Study Script

Step 1- Introduction

Script: "Hello everyone, thank you for joining us today. Can we please get your consent to participate in our game?

Step 2- Explanation of Red Light, Green Light

Script: "Hello everyone, thank you for joining us today. Does everyone know how to play the game Red light, Green Light? If not, I will go over the game that you will be participating in today."

"The game of red light greenlight goes as follows: Each participant starts on the line and a corresponding number. When the individual leading the game, which in this case is the robot, turns its head, you can move towards the robot, but when it turns its head back, and is looking at you, you cannot move. If the robot sees you move, you are out of the game. You will know this by one of three cues being light, movement, and noise. If the robot calls your number, moves towards you, or blinks in the number corresponding to your number, you are out and you can exit the game. The way to win is to be the first individual to reach the robot and poke it with your foot. "

"Now the game will start!"

Step 3 - Receiving feedback through rating scales of 1-5 that asks the participants questions about efficiency of the signals and comfortableness with the game and robot.

Script: "Now if you all would be so kind, can you please fill out our post experimentation survey"

"Also, if you have any additional feedback, please write it on the white space provided on the back of the survey"

Step 4- Debrief: Thanking the participants

Script: "That is everything we've prepared for you today. The goal of this study was to conduct the game of Red Light, Green Light utilizing the Turtlebot 4 to detect movement and notify participants if they are eliminated from the game through different cues and observe their behavior. Thank you all so much for participating and taking out the time of your busy schedules."

Figure 10: Script

A.4. Post-Study Surveys

The Post Survey study measures the participants perception of comfertability, effectiveness of robotic cues, and recognization of signals.

Post-Study Survey

Please answer the following question and rate your comfort level.

What is your comfort level from 1 (Very Uncomfortable) to 5 (Very Comfortable) during the Red Light, Green Light game.

1 - Very Uncomfortable
2- Uncomfortable
3 - Neutral
4 - Comfortable
5 - Very Comfortable

From 1 (Inefficient) to 5 (Efficient), can you rate your experience when the robot communicates with you using sound.

1 - Very Inefficient
2- Inefficient
3 - Neutral
4 - Efficient
5 - Very Efficient
6- N/A

From 1 (Inefficient) to 5 (Efficient), can you rate your experience when the robot communicates with you using movement.

1 - Very Inefficient
2- Inefficient
3 - Neutral
4 - Efficient
5 - Very Efficient
6- N/A

Figure 11: Post study survey part 1

From 1 (Inefficient) to 5 (Efficient), can you rate your experience when the robot communicates with you using light.

1 - Very Inefficient
2- Inefficient
3 - Neutral
4 - Efficient
5 - Very Efficient
6- N/A

How well do you recognize the signal that is given to you? (1 Worst) (5 Best)

1 - Very Unrecognizable
2- Unrecognizable
3 - Neutral
4 - Recognizable
5 - Very Recognizable
6- N/A

What is your comfort level from 1 (Very Uncomfortable) to 5 (Very Comfortable) with the appearance of the robot.

1 - Very Uncomfortable
2- Uncomfortable
3 - Neutral
4 - Comfortable
5 - Very Comfortable

Figure 12: Post study survey part 2