Enhancing Human-Robot Interaction in Healthcare: A Study on Nonverbal Communication Cues and Trust Dynamics with NAO Robot Caregiver

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Outline

- Introduction
- Existing Works
- Problem Statement
- Objectives
- Research Questions
- Methodology
- Results
- Discussion
- Conclusion
- Limitations and Future Works
- References

Introduction

- According the Organization for Economic Co-operation and Development (OECD), by the middle of the 21st century, over 20% of the world's population will be aged 65 and over [1].
- As the population of older adults increases, so will the need for both human and robot care providers.
- Traditional caregiving practices often involve hiring human caregivers, which expensive and may not always effectively meet the needs of older adults.
- Human-robot interaction (HRI) is a rapidly expanding discipline exploring how humans and robots work together [2].

Introduction (Cont.)

- Non-verbal behaviors of robots, body movement, hand gesture, touch, are facilitating effective communication and interaction between humans and robots [3].
- By adjusting their non verbal behaviors, robots can express empathy, and understanding, enhancing interaction quality and fostering trust and engagement.
- This study explores the integration of Nao's nonverbal behavior, in health monitoring and caregiving for older adults.

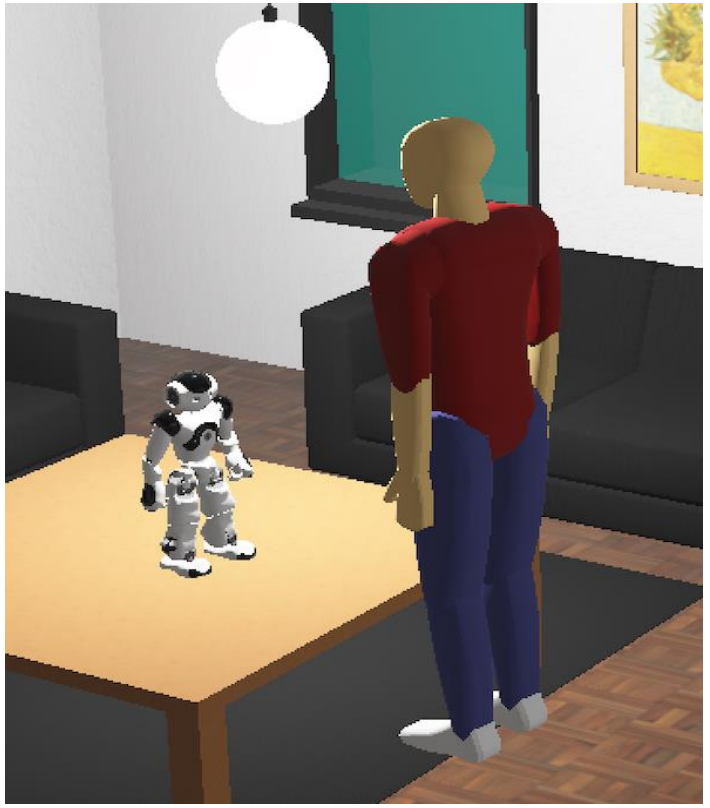


Fig. 1 : Webot simulation of apartment with Nao robot as caregiver

Existing Works

- **Mazursky *et al.*** [4]
  - Investigate the impact of robot-initiated touch in healthcare settings, specifically focusing on factors influencing patient experience.
  - Explored how different variables such as touch presence, robot intent, appearance, and tone affect participant reactions.

- **Johnson *et al.*** [5]
  - Explore the entertainment value of playing games with a humanoid robot Nao, particularly focusing on the game Mastermind.
  - Investigated the impact of multimodal behavioral patterns, which combined gestures, eye LED patterns, and speech to imitate various emotions.

Existing Works (cont.)

- **Akalin *et al.*** [6]
  - Conducted a study to demonstrate the effectiveness of a Pepper robot equipped with non-verbal gestures for elder care
  - Enhance security and safety aspects in caregiving environments using the robot's arm gestures and head nodding.

Problem Statement

- Only few studies worked with robot for caregiver the older people
- Need of specific application to the design and implementation of robotic caregivers like Nao in real-world settings.
- Trust issue when Nao touch the older adults for the purpose of medical care

Objectives & Contributions

- Design the Nao robot with and elderly adults in healthcare setting
- Manipulate nonverbal communication modalities, specifically unique combination of **gestures** and **LED patterns** and **touch** respectively.
- Employ a **mixed-methods approach** with **within-subject factorial** design for assessing participant responses to different types of interactions and cues
- Design the robot capabilities of serving the needs of the elderly to improve the quality of life for older adults

Proposed Methodology

Research Questions

1) RQ1: How the participants perceive when robot Nao touches to observe and monitor the participant's health?
   - Explore participants' comfort levels, trust in the robot's capabilities, and overall satisfaction during touch-based monitoring.

2) RQ2: Can participants effectively understand and respond to various LED light patterns and gestures (hand and head movement) from the Nao robot?
   - Assess participants' understanding and responsiveness to various nonverbal cues.
   - Evaluate either LED light patterns or hand gestures better.

3) RQ3: What distinguishing factors influence trust between interactions involving human-human versus human-robot dynamics, specifically between older adults and care providers?
   - Investigate the factors influencing trust in interactions between older adults and robotic caregivers versus human care providers

Overall Design

- Design our overall scenario using **Webots** simulation due to the lack of Nao Robot
- To evaluate our research questions we developed the various nonverbal cues:
  - **Touch by Nao**
  - **Hand and head gestures by Nao**
  - **LED patterns used by Nao**

Environmental Setup:

- Environment consists of the Nao robot placed within an apartment with elderly adults
- To simulate realistic interactions between older adults and the robot, we have devised **two video scenarios**
- The Nao robot interacts with older adults to monitor people's health conditions.

Scenario 1: Positive Responses

- In an apartment, an elderly individual stands in front of the Nao robot positioned on a table
- Nao moves towards the elderly individual's hand to check their health condition through touch
- The Nao robot interacts with older adults to monitor elder's health conditions.
- If heath is **good** then Nao express the positive vibes by
  - Change **LED** lights to **green**
  - Raise its **arms** in **a welcoming gesture**
  - Nods its **head up and down**

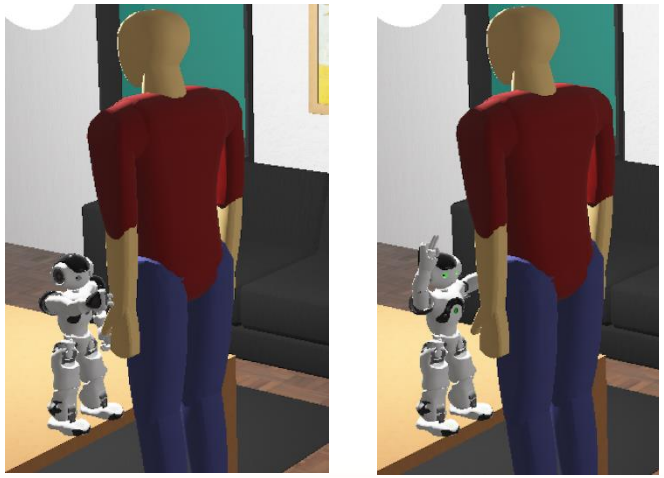


Fig. 2 : Positive gestures of Nao Robot

Scenario 2: Negative Responses

- If heath is **not good** then Nao express the negative vibes by
  - Change **LED** lights to **red**
  - Lift its **arms to head**
  - Nods its **head left and right**

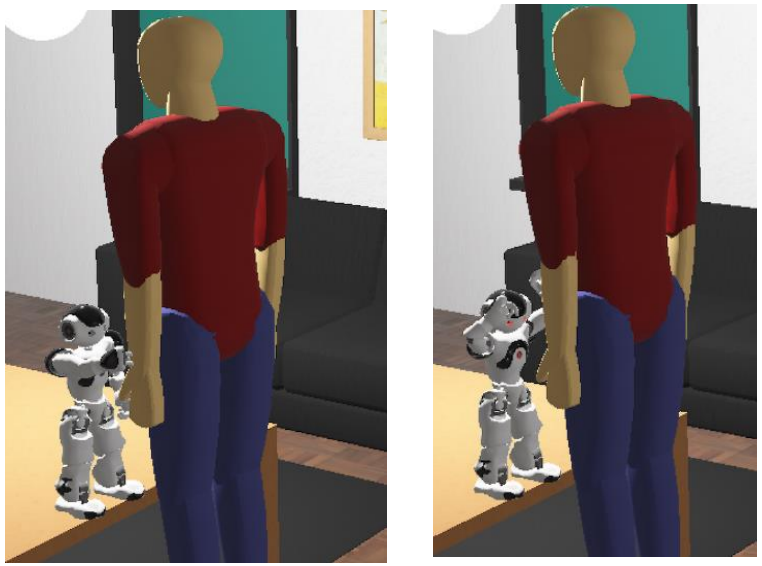
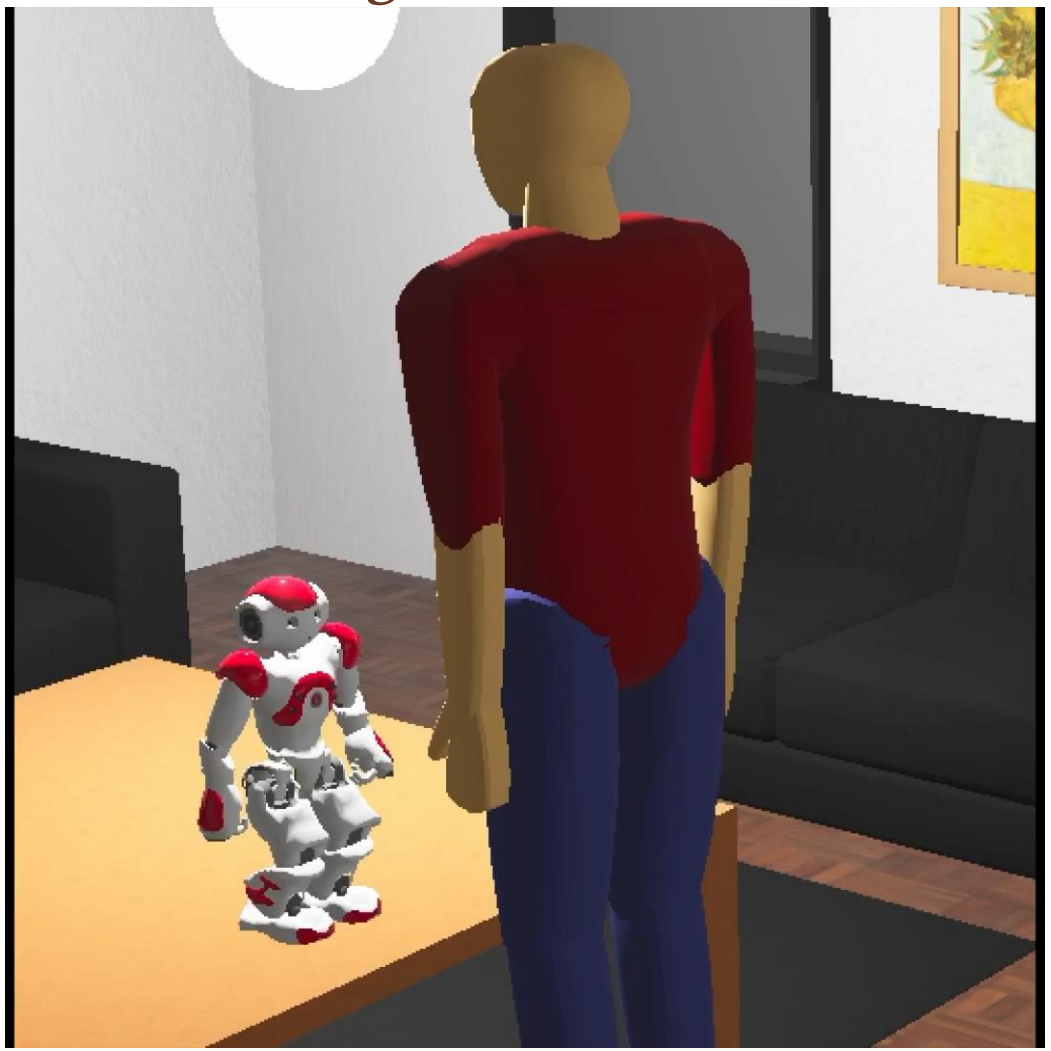


Fig. 3 : Negative gestures of Nao Robot

Scenario 1: Positive Gesture

Scenario 2: Negative Gesture



Manipulated Nao Touch Behavior

- Nao has various basic commands and behaviors

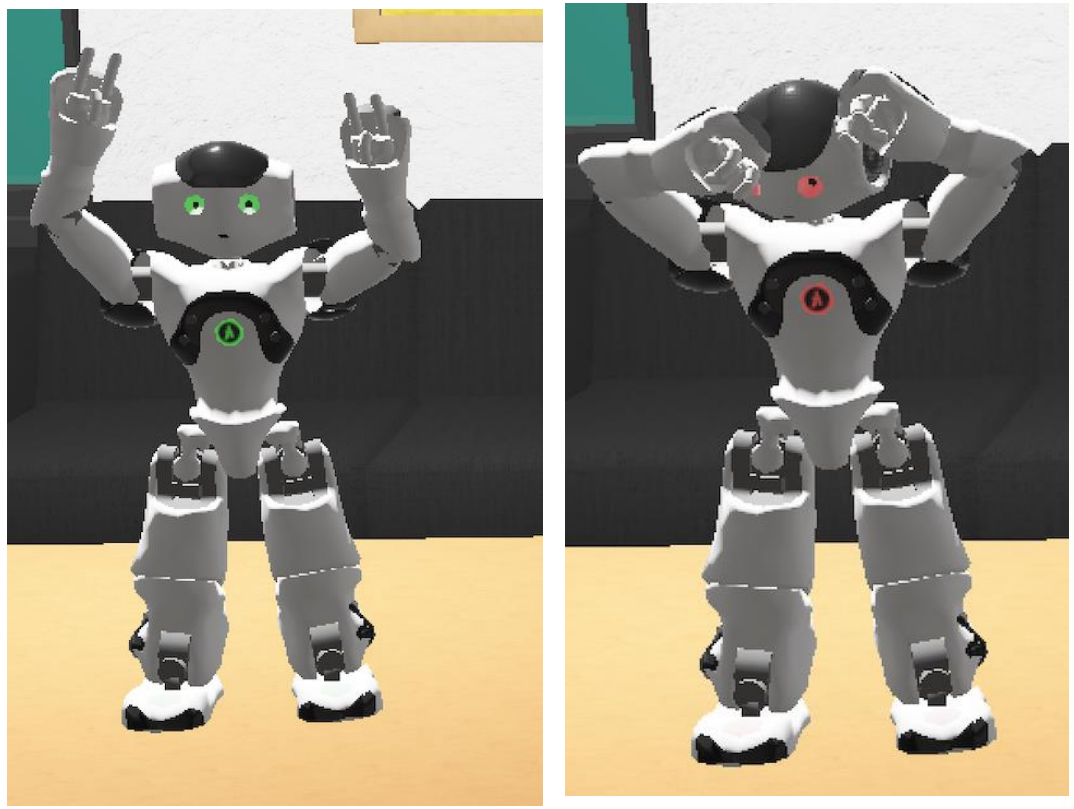
1) Touch Manipulation

- Nao robot has nine tactile sensors and eight pressure sensors [7]
- In Webots simulation, it was challenging to manipulate the Nao sensors
- ***rand()*** function, which generates either **1 or 0** when the Nao robot touches a human
- When Nao generates a **1**, it indicates a **good health** condition or **positive vibes**
- When Nao generates a **0**, it indicates a poor health condition or **negative vibes**

Manipulated Nao Touch Behavior (cont.)

2) Hand and Head Gestures Manipulation

- Nao uses these basic commands to navigate towards adult individuals.
- We introduced **three new hand gestures** for health monitoring purposes: ***handshake(), sadmotion(), and happymotion()***
- When Nao generates a **1**, it indicates the ***happymotion()***
- When Nao generates a **0,** it indicates the ***sadmotion(),***

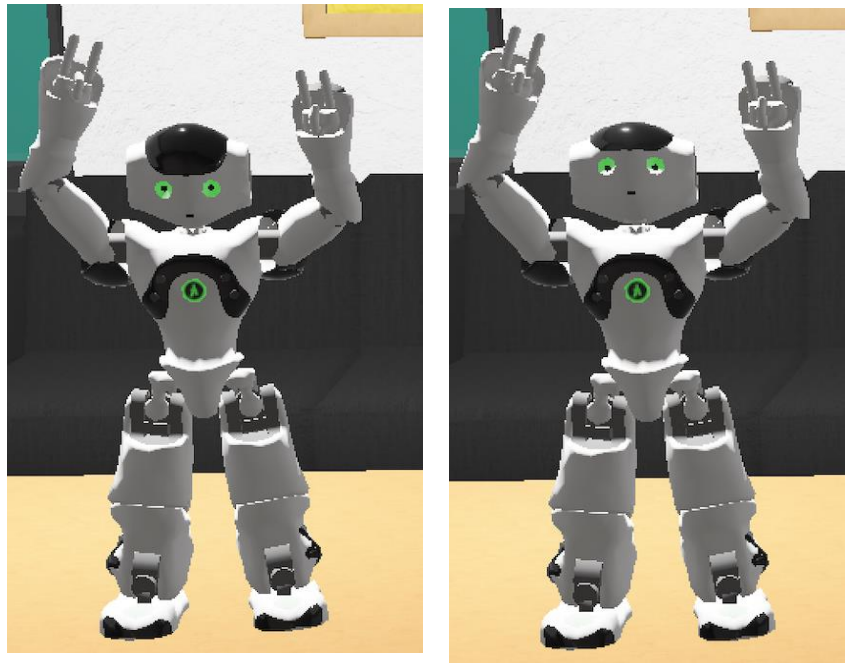


(a) Positive (b) Negative

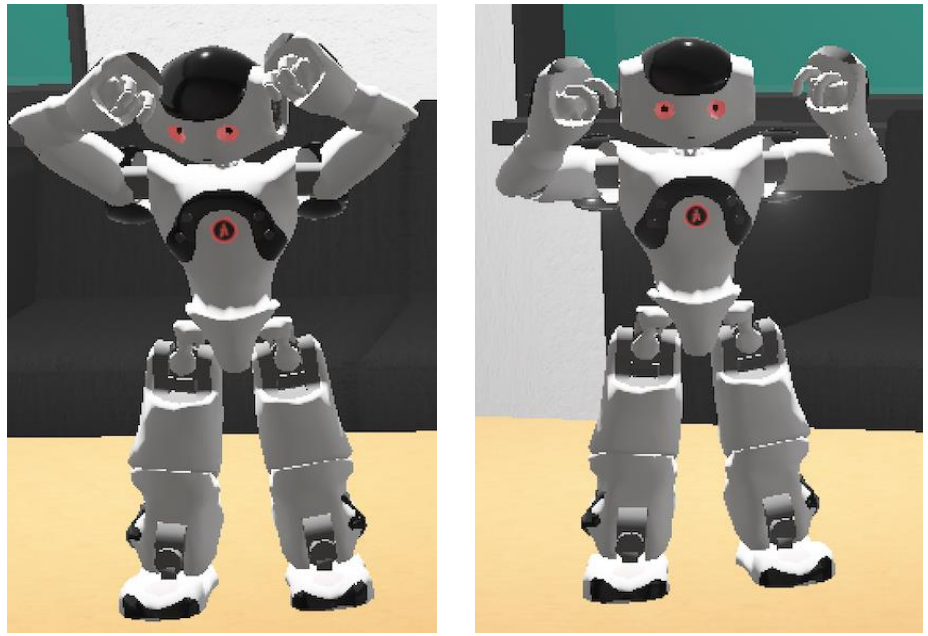
Fig. 4 : Snapshot of the Nao robot displaying: (a) Positive gesture the robot raises its arms and (b) negative gesture the robot lifts its arm to its head.

Manipulated Nao Touch Behavior (cont.)

2) Hand and Head Gestures Manipulation (cont.)



(a) Nodding the head up and down



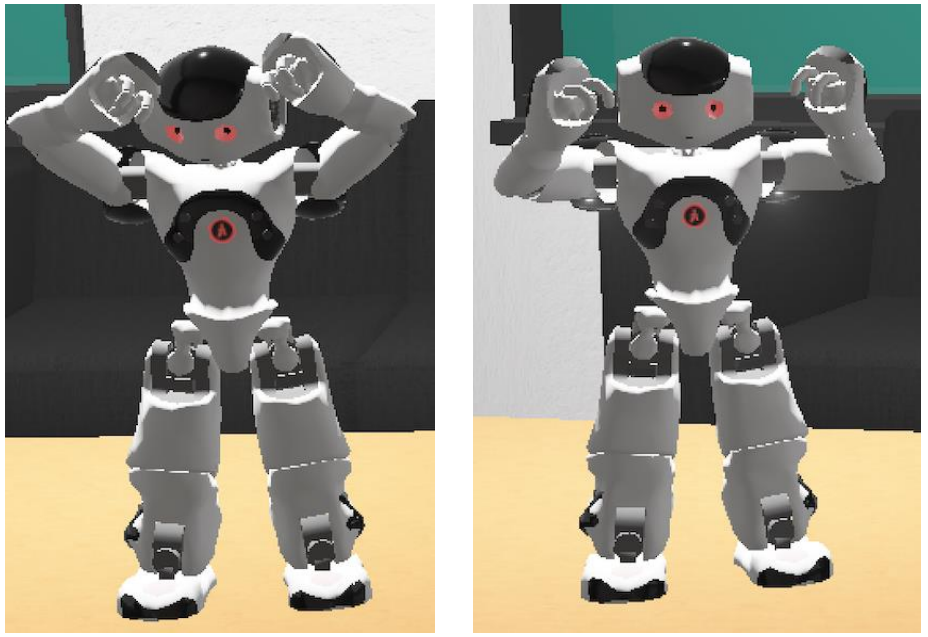
(b) Nodding the head left to right

Fig. 5 : Snapshot of the Nao robot displaying: (a) Positive gesture and (b) Negative gesture

Manipulated Nao Touch Behavior (cont.)

3) LED Patterns Manipulated

- Manipulate the Nao robot's **two eye LEDs** and **ChestBoard LED**.
- Nao receives a value of 1, it shows the **happy expression** and changes the LED pattern **GREEN** color
- Nao receives a value of 0, it shows the **sad expression** and changes the LED pattern **RED** color



(a) Green Color (b) Red Color

Fig. 6 : Snapshot of the Nao robot displaying: (a) Positive gesture and (b) Negative gesture

Participants

- **Survey: Google Forms questionnaire** that contained links to two simulation videos.
- **Eight students**, aged between 22 and 28 (with **ME= 24.75 and SD = 1.98**), from the University of Waterloo
- All participants had prior experience with robot interaction.

Procedures

- When the experiment starts, participants are requested to provide **demographic details** and complete a survey evaluating the Nao robot on its **non-verbal cues**.

- Participants are shown two video scenarios featuring a robot caregiver conducting a medical screening

Measures

- The research questions aimed to evaluate participant experiences and perceptions in three main domains: **perception, nonverbal communication efficiency (either LED or hand gesture, trustworthiness (4 independent variable)**

- Questionnaire items were assessed participant agreement on **a 5-point Likert scale ranging** from **1 Strongly Disagree) to 5 (Strongly Agree)**

- Employ **mixed-methods approach** with a **within-subject factorial** design for assessing participant responses based on **4 independent** variables and **11 dependent variables**.

Measures (cont.)

- **Perception (for RQ1):** Participants assessed specific aspects of **Nao's touch-based** health monitoring: **tractability, comfortability, competency, and reliability**

- **Efficiency of Nonverbal Communication (for RQ2):** Participants assessed the **effectiveness, understandability, and accuracy**

- **Trustworthiness (for RQ3):** Participants provided feedback on the following topics: **interactivity, relationship dynamics, dependence, trust level**

Results and Discussion

Result Analysis

❖ Perception (RQ1)

- Participants viewed Nao's touch-based health monitoring favorably, with a scope for enhancing **comfort** and **confidence** levels further.

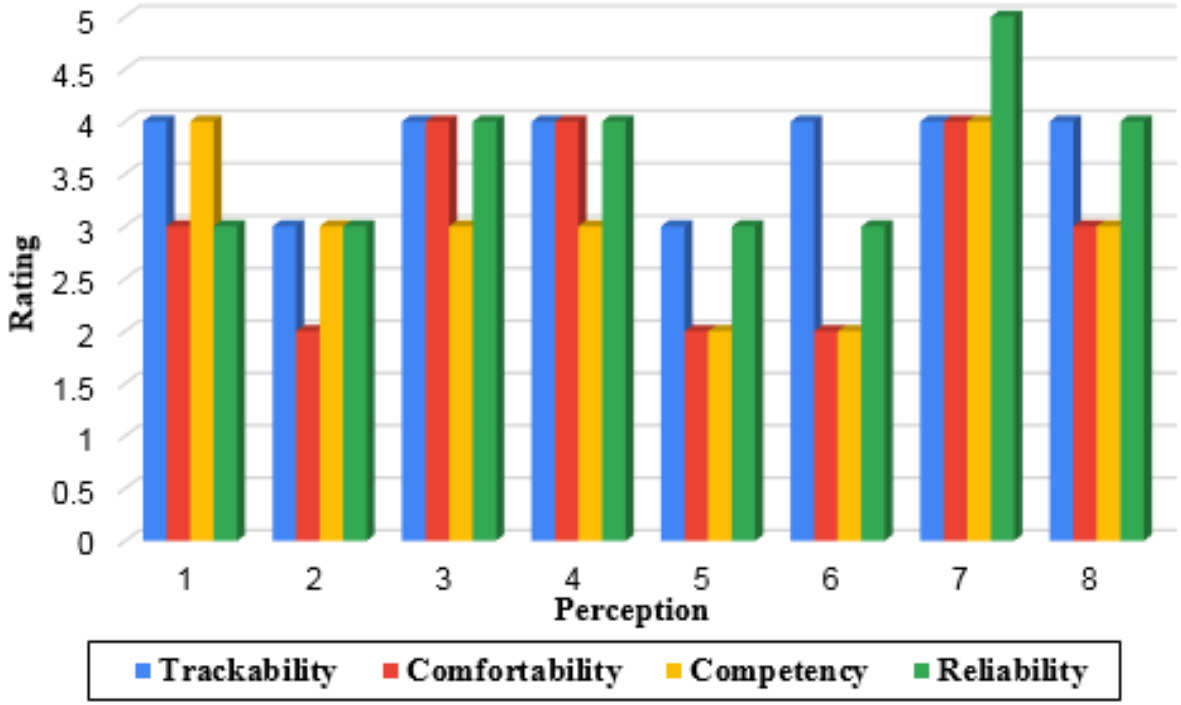


Fig. 7 : Perception of touch rated against tractability, comfortability, competency, and reliability

Result Analysis

❖ Efficiency of Nonverbal Communication (RQ2)

- **LED patterns** are perceived as better than **hand and head gestures** in terms of understandability and accuracy

TABLE I
STATISTICAL DESCRIPTION FOR NON-VERBAL COMMUNICATION EFFICIENCY OF LED APPROACHES OR HAND AND HEAD GESTURES.

Evaluation	Effectiveness	Understandability	Accuracy
$p-$value	0.133	0.020	0.005
$t-$value	1.694	3.055	4.098
Effect size	0.742	1.058	1.493
LED ME±SD	4.12 ± 0.83	4.25 ± 0.46	4.37 ±0.51
H&H ME±SD	3.62±0.48	3.75±0.48	3.62±0.53

* H&H = Hand and Head gestures, ME = Mean value, SD = standard deviation.

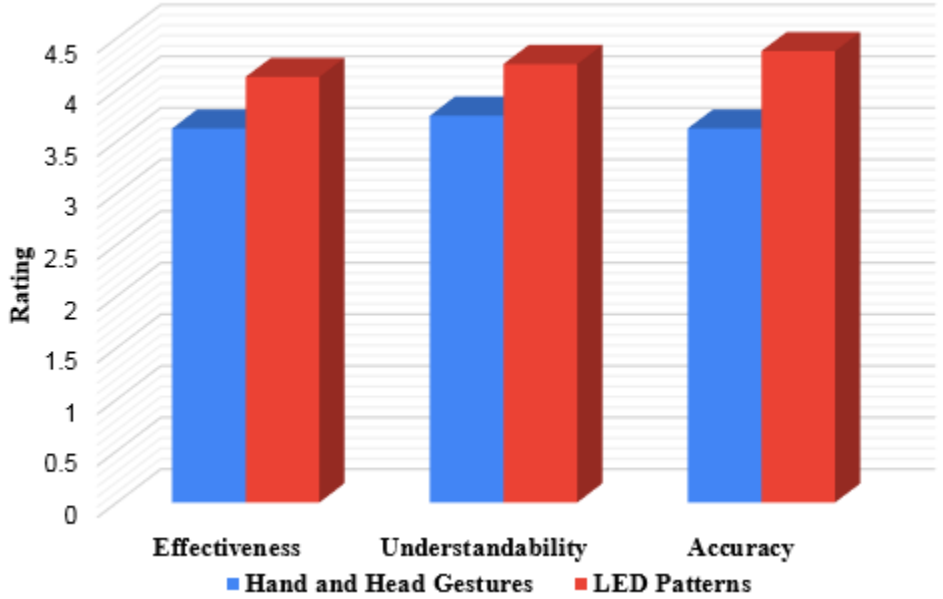


Fig. 8: Non-verbal communication efficiency (either LED or hand gesture approaches) rated against effectiveness, understandability and accuracy.

Result Analysis

❖ Trustworthiness (RQ3)

- Participants recommended Nao rather than human caregiver.

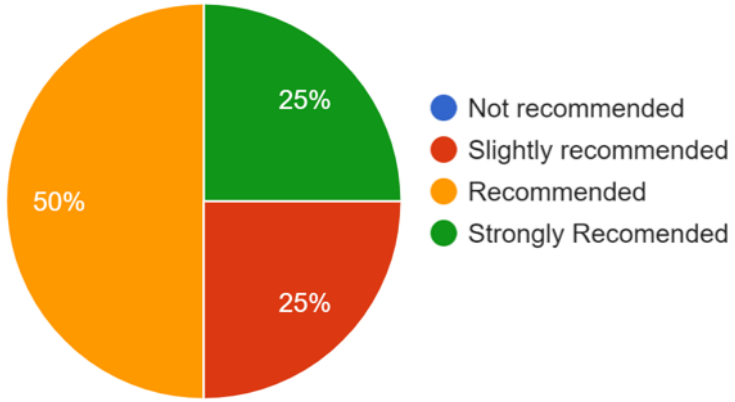


Fig. 8: Percentage of Trust Level

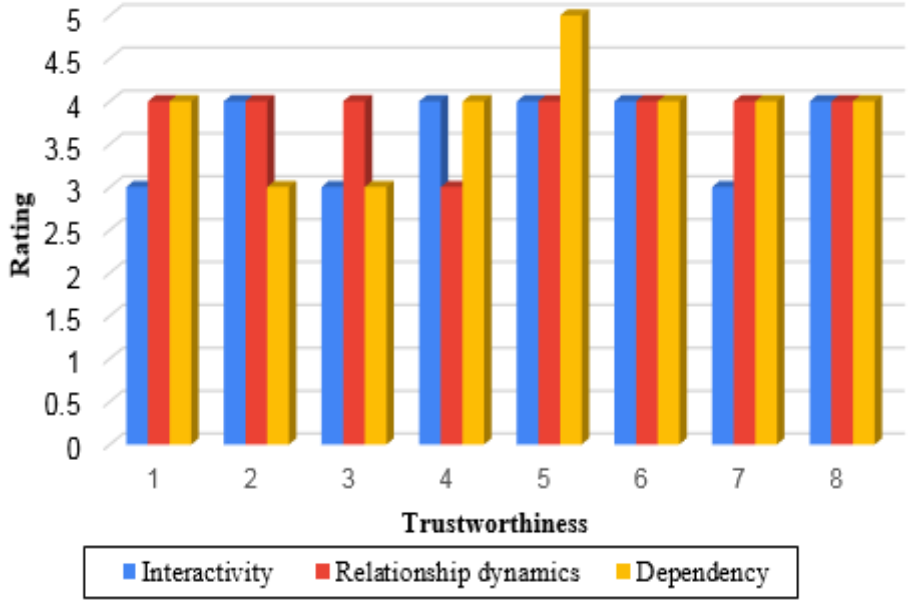


Fig. 9: Trustworthiness rated against interactivity, relationship dynamics, and ndependency

Discussion

- Nao's touch-based health monitoring: Easy to understand, moderately comfortable, competent, and reliable.

- **LED patterns vs. gestures:** LED patterns favored for understandability and accuracy.

- **Trust dynamics:** Longer interactions correlated with increased trust, emphasizing importance of engagement.

Conclusion

- Our findings suggest that Nao's touch-based health monitoring was well-received by participants, with positive ratings
- We can conclude Nao can be used as an caregiver for monitoring the health condition of Elderly people

Limitation & Future Works

- Sample size in this study is very small. In future studies, efforts should be made to expand participant recruitment
- Moreover, conducting the study without ethical approval raises ethical concerns regarding participant consent and data privacy.
- We have designed in Webots simulation, however, real scenarios could be more complex.

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Any Questions?