# Lecture 01: Recap

## Think and Write in 1 Minute

- Write down any three things that we learned in the previous lecture.

Participants can vote at **Slido.com** with **#1316882**
and the passcode: tqkdio

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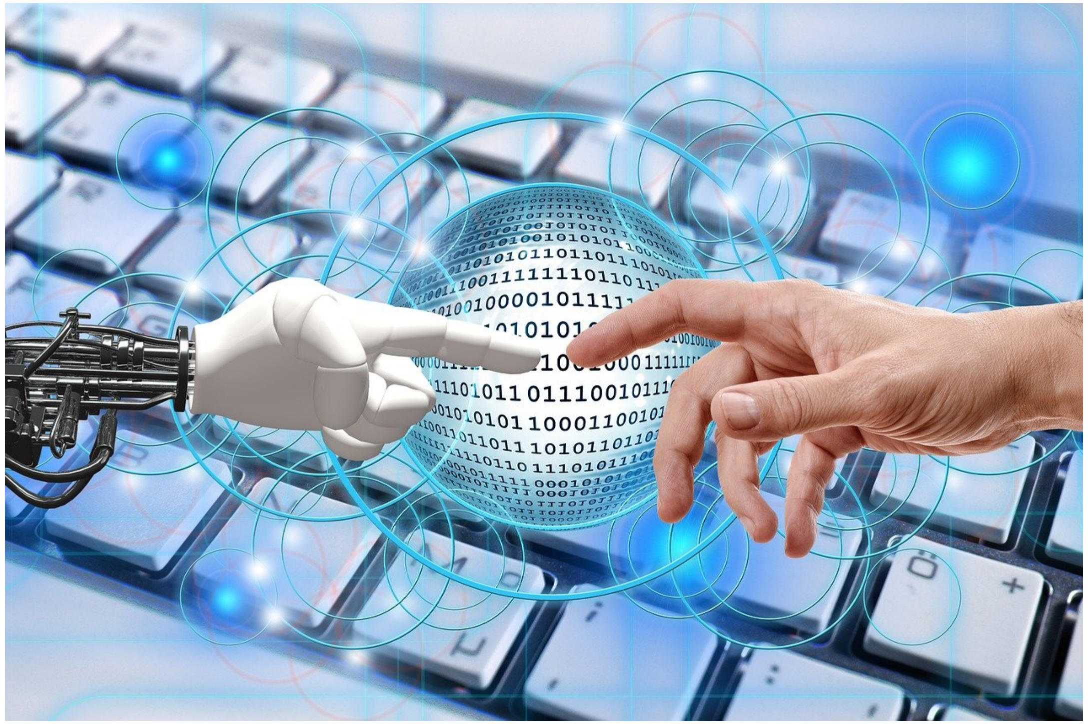
# Structuring and Analyzing Human-Robot Interaction



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Sankt Augustin

18th April 2024

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# Learning Goal

- At the end of today's lecture, you will be able to:
    - Identify the elements of human-robot interaction.
    - Explain the need for a taxonomy for human-robot interaction.
    - Characterize human-robot interaction scenarios with the help of a taxonomy.
    - Apply the taxonomy to compare different human-robot interaction scenarios.

- This lecture is primarily based on the following paper:
    - Onnasch, L., Roesler, E. A Taxonomy to Structure and Analyze Human–Robot Interaction. *Int J of Soc Robotics* **13,** 833–849 (2021). https://doi.org/10.1007/s12369-020-00666-5

# Reading Assignment: Summary

- Take-away messages
- Difficult to understand

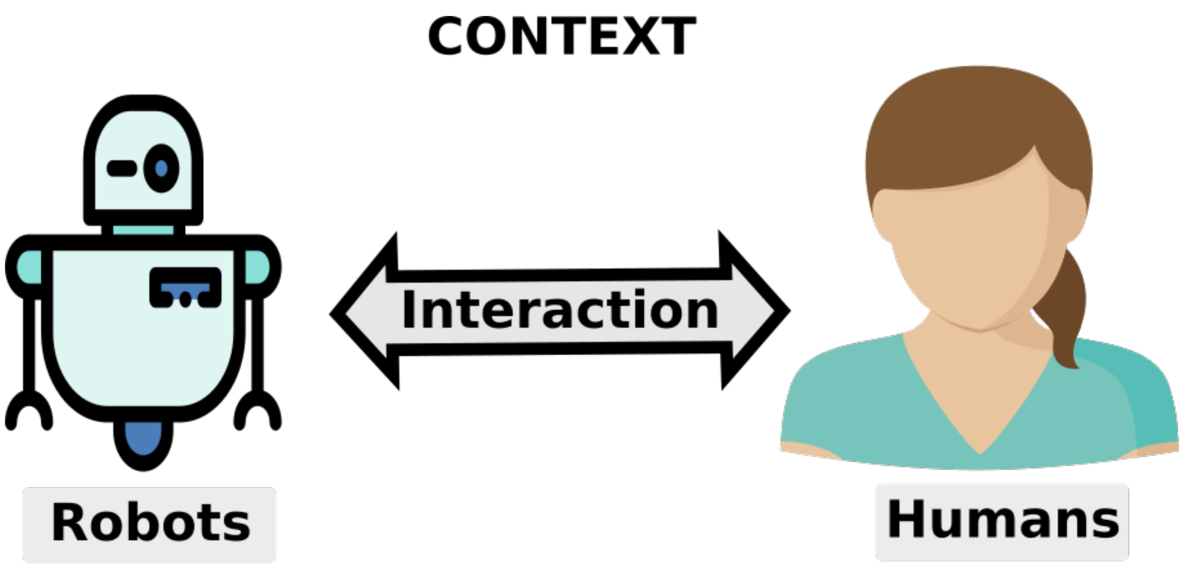
# Variability in Human-Robot Interaction Scenarios


https://youtu.be/2ZUn9qtG8ow


https://youtu.be/hEgJOmRkAKg

What differences do you observe between the two scenarios?

# Human-Robot Interaction: Elements




- **Interaction partners**
  - Humans and robots
  - Their respective roles
- **Interaction:** Type and level, frequency, time duration, modalities, etc.
  - Types: Physical, verbal, nonverbal
  - Coexistence, cooperation, collaboration
- **Interaction context**
  - Application domain
  - Purpose / goal of interaction
  - Interaction setting
    - Controlled versus uncontrolled
    - Active versus passive

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# Reproducibility and Comparability

- Wide range of robots and application fields.
- Therefore, a lot of variability is possible in human-robot interaction scenarios.
- Common practice: Experiments are based on individual use cases.
- Challenges:
  - Results from a single experiment (use case) cannot be generalized.
    - Experiments and scenarios should be **reproducible**.
  - Conflicting results from experiments evaluating similar hypotheses are difficult to explain.
    - Experiments and scenarios should be **comparable**.
- Reproducibility and comparability of experiments are necessary to advance the knowledge about the field of human-robot interaction.

# The Problem and The Solution

- Why is reproducibility and comparability difficult in human-robot interaction?
  - Omission of important details describing the interaction scenario and experimental s etting.
  - Use of inconsistent terminology with different semantics.
- Solution:
  - We need **a common language** to **completely describe** any human-robot interaction scenario.
    - In other words, all elements and aspects of a human-robot interaction scenario should be describable using standard, commonly agreed terminologies.
    - That is to say, we need a **taxonomy**!

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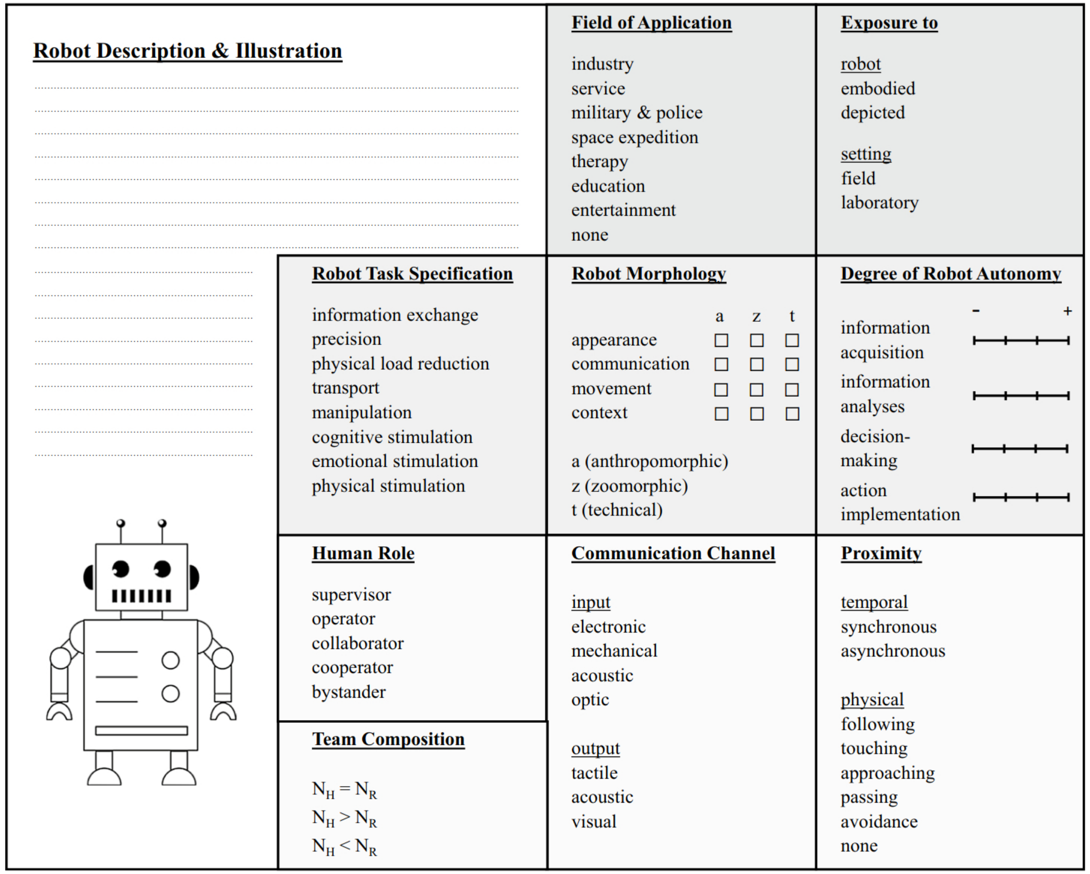
# HRI Taxonomy: Overview

- Onnasch and Roesler (2021) proposed a three-level taxonomy to describe the different elements of a human-robot interaction scenario.
- This taxonomy takes inspiration from, combines and extends several existing frameworks proposed in literature.
- Hierarchical framework
  - First layer (top): Classifies interaction context
  - Second layer: Classifies the robot
  - Third layer: Classifies the human-robot team

**Fig. 1 of Onnasch, L., Roesler, E. A Taxonomy to Structure and Analyze Human–Robot Interaction. *Int J of Soc Robotics* 13, 833–849 (2021). https://doi.org/10.1007/s12369-020-00666-5**




This canvas is downloadable from https://www.psychologie.hu-berlin.de/de/prof/ingpsy/hri-taxonomy/psychofinalll.pdf

# Work with the HRI Canvas

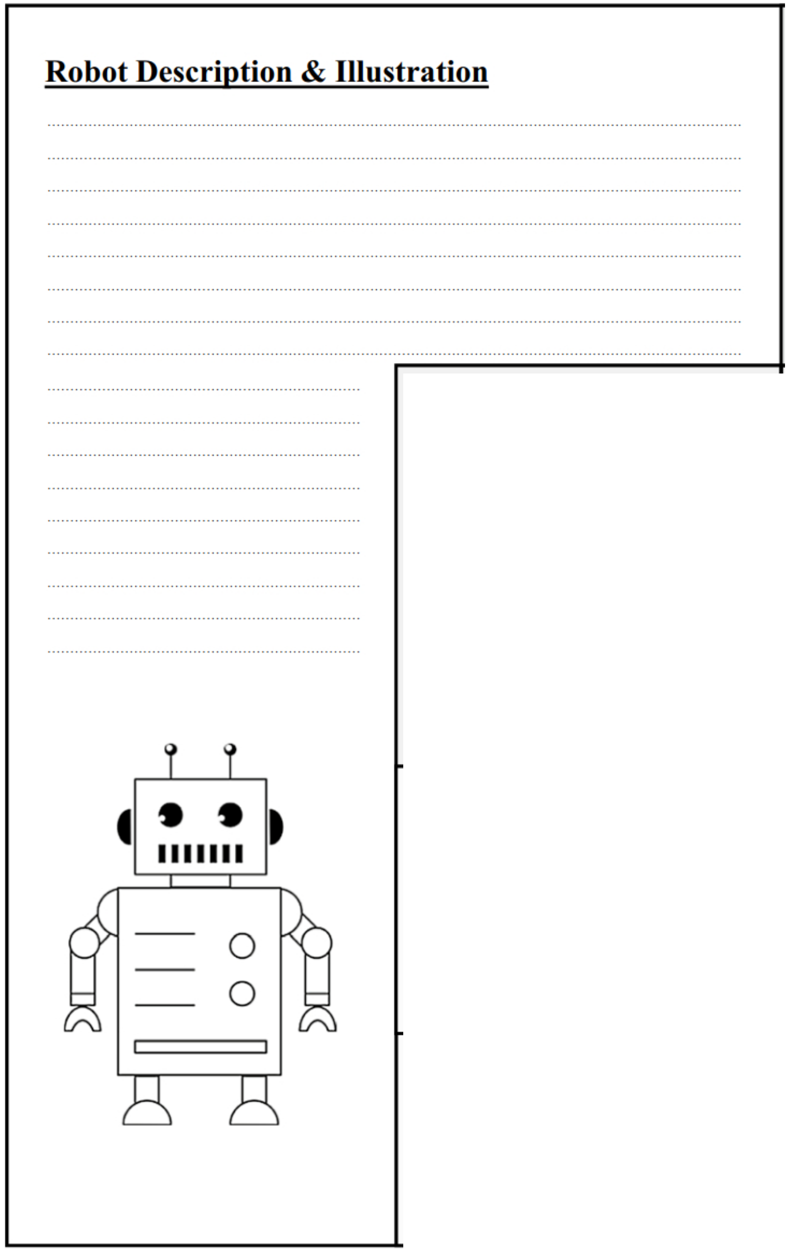
- Download the canvas from supplementary materials of Homework #1.
- Can you edit the PDF digitally?
- Create two copies – one for each example shown in the videos on previous slide.
- Work in pairs.
- For each quiz, discuss and fill in the corresponding fields in both sheets.

# Quiz 1 – Robot Description and Illustration

- Name the robot used in the scenario.
- How is its mechanical construction?
- Where is it used in the scenario?
- What tasks does it have to perform in the scenario?

- High-level description

- Make a sketch of the robot! ☺



# Layer 1: Interaction Context Classification

## Field of Application

- What is the field of application of the interaction with robots?

| Field of Application | Exposure to |
|---|---|
| industry | robot |
| service | embodied |
| military & police | depicted |
| space expedition | |
| therapy | setting |
| education | field |
| entertainment | laboratory |
| none | |

## Exposure to

- What form of representation of the robot is the human subject exposed to?
  - Embodied
    - A physical robot whose body can be touched
  - Depicted
    - Virtual agents (or, computer animations)
    - Videos or images of robots
- Where is the interaction taking place?
  - Laboratory
    - A controlled setting
  - Field
    - Outside a laboratory, "in the wild"

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# Fields of Application

- Industry – e.g. assistance at assembly lines
- Service – lawn mowing, vacuum cleaning, etc.
- Military and police – bomb disposal, wildfire control, search and rescue, ...
- Space expedition – exploring astronomical bodies
- Therapy – behavioral therapy, rehabilitation
- Education – language learning, solving mathematical problems
- Entertainment – for use as pets or toys
- None – when no information is provided about the field of application in the study description.

- Based on the field of application, we can predict the general characteristic of both the human users as well as the environment.

# Quiz 2 – Characterize the Interaction Context

| **Field of Application** | **Exposure to** |
|---|---|
| industry | robot |
| service | embodied |
| military & police | depicted |
| space expedition | |
| therapy | setting |
| education | field |
| entertainment | laboratory |
| none | |


https://youtu.be/2ZUn9qtG8ow

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# Layer 2: Robot Classification

- Robot task specification
  - What task does the robot perform in the field of application?
    - An abstract goal or purpose of the interaction.
- Robot morphology
  - How does the robot look?
  - What does it resemble when it communicates or moves?
  - How is it framed in the interaction context?
- Degree of robot autonomy
  - How much human intervention does the robot need in order to interact?

| Robot Task Specification | Robot Morphology | | | | Degree of Robot Autonomy | - + |
|---|---|---|---|---|---|---|
| information exchange | | a | z | t | | |
| precision | appearance | ☐ | ☐ | ☐ | information acquisition | |
| physical load reduction | communication | ☐ | ☐ | ☐ | information analyses | |
| transport | movement | ☐ | ☐ | ☐ | decision-making | |
| manipulation | context | ☐ | ☐ | ☐ | action implementation | |
| cognitive stimulation | | | | | | |
| emotional stimulation | a (anthropomorphic) | | | | | |
| physical stimulation | z (zoomorphic) | | | | | |
| | t (technical) | | | | | |

# Robot Task Specification

- **Information exchange**
  - Gather, analyse and transfer information to humans
    - E.g. Space / underwater exploration missions, search and rescue
- **Precision**
  - Tasks like minimally invasive surgeries that require high precision
- **Physical load reduction**
  - Reduce the physical load or physical effort of humans to do a specific task
    - E.g. to walk, to lift heavy objects, carry objects over a distance, fix objects, etc.
- **Transport**
  - Transport objects from one location to another.
    - E.g. in warehouses, hospitals
- **Manipulation**
  - Physically modifies the environment
    - E.g. welding, pick and place
- **Cognitive stimulation**
  - Engage user at cognitive level through verbal and nonverbal communication, e.g. to educate, train.
- **Emotional stimulation**
  - Stimulate emotional expressions and reactions during interaction.
    - Verbal, nonverbal communication
    - Through companionship, entertainment
- **Physical stimulation**
  - Rehabilitation support to regain control or stability of physical body functions

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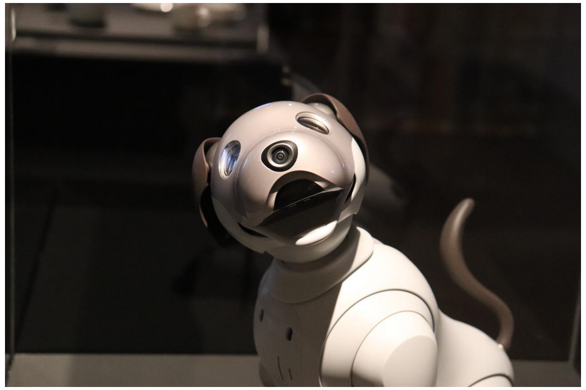
# Robot Morphology

- Why is it important for interaction?
  - Creates expectations about functional and communicational capabilities of the robot.
    - If a robot looks like a human, then the user would expect to interact with it verbally.
    - Resemblance with known objects enables an intuitive interaction.
- Anthropomorphic, zoomorphic or technical
  - In: appearance, communication, movement, context (framing)

**Anthropomorphic**



**Zoomorphic**

**Technical**

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# Framing

- In the social sciences:
  - *"To frame is to* ***select some aspects*** *of a perceived reality and* ***make them more salient*** *in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/ or treatment recommendation for the item described."* -- *Framing*: Toward *clarification of a fractured paradigm*. *Entman, Robert* M. Journal of Communication; Autumn *1993*; 43, 4; ABI/INFORM Global.
- Through personified or zoomorphic narratives, even a technical-appearing robot can be made to be perceived as a child or a pet.
- Framing is done in human-robot interaction experiments or studies in the form of a narrative (a story).
  - Provides info about the context of the interaction.

# Degree of Robot Autonomy

- Autonomy:
  - *"The extend to which a robot can operate in the tasks it was designed for (or that it creates for itself) without external intervention."* -- Baraka et al. (2020).

- Four stages of doing a task:
  1. Information acquisition
  2. Information analyses
  3. Decision-making / Action selection
  4. Action implementation

- Autonomy in doing each stage of a task
  - For practical convenience, three levels:
    - low/none, medium, high/complete

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# Quiz 2 – Characterize the Robot

| Robot Task Specification | Robot Morphology | | | | Degree of Robot Autonomy | - … + |
|---|---|---|---|---|---|---|
| information exchange | | a | z | t | | |
| precision | appearance | ☐ | ☐ | ☐ | information acquisition | ├──┼──┼──┤ |
| physical load reduction | communication | ☐ | ☐ | ☐ | information analyses | ├──┼──┼──┤ |
| transport | movement | ☐ | ☐ | ☐ | decision-making | ├──┼──┼──┤ |
| manipulation | context | ☐ | ☐ | ☐ | action implementation | ├──┼──┼──┤ |
| cognitive stimulation | | | | | | |
| emotional stimulation | a (anthropomorphic) | | | | | |
| physical stimulation | z (zoomorphic) | | | | | |
| | t (technical) | | | | | |


https://youtu.be/2ZUn9qtG8ow

# Layer 3: Team Classification

- **Human role**
  - What role does the human play in the interaction?
- **Team composition**
  - How many humans and robots are involved in the interaction?
    - Exact numbers can be specified.
- **Proximity**
  - Spatial
    - Physical distance between the workspaces of the human and the robot.
  - Temporal
    - Do the humans and robots work at the same time?
      - Yes ==> Synchronous
      - No ==> Asynchronous
- **Communication channel**
  - Input:
    - How can the robot perceive the human?
    - How can information flow from human to robot?
  - Output:
    - Which of the human senses are involved in receiving information from the robot?

| Human Role | Communication Channel | Proximity |
|---|---|---|
| supervisor<br>operator<br>collaborator<br>cooperator<br>bystander | input<br>electronic<br>mechanical<br>acoustic<br>optic | temporal<br>synchronous<br>asynchronous |
| **Team Composition**<br>$N_H = N_R$<br>$N_H > N_R$<br>$N_H < N_R$ | output<br>tactile<br>acoustic<br>visual | physical<br>following<br>touching<br>approaching<br>passing<br>avoidance<br>none |

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# Human Role

- **Supervisor**
  - Monitors and gives instructions.
- **Operator**
  - Controls the robot
    - Direct control of robot's actions.
    - Changes internal implementation, when behaviour not acceptable.
- **Collaborator**
  - Humans and robots share same goals and subgoals and work jointly.
- **Cooperator**
  - Humans and robots do different tasks to fulfil the shared overall goal.
- **Bystander**
  - No interaction, no shared goals, but share the same space.
    - Mental models of the robot and its actions are still necessary to avoid collisions.
    - E.g. Passers-by who try to avoid collisions with a mobile robot.

# Spatial Proximity

- In decreasing order of physical proximity:
  - Following
    - Stable physical contact for longer time. E.g. using joystick or manipulating same objects.
  - Touching
    - Share the same workspace and interact directly with physical contact.
  - Approaching
    - Work closely in the same space but no physical contact.
  - Passing
    - Workspaces overlap partially or fully, but contact is prevented.
  - Avoiding
    - Workspaces not close to each other, and contact is avoided.
  - None
    - Work in different environments (e.g. different planets, watching videos of a robot).

# Communication channels

- **Input to robot from human**
  - Electronic
    - E.g. remote control, joystick, touch screen, etc.
  - Mechanical
    - E.g. movement of the robot's arm
  - Acoustical
    - E.g. verbal instructions
  - Optical
    - E.g. gestures

- **Output from robot to human**
  - Tactile
    - E.g. vibrations
    - Human sense of touch
  - Acoustical
    - E.g. tones, animal sounds
    - Human sense of sound
  - Visual
    - E.g. robot's body movements

# Quiz 3 – Characterize the Team

| **Human Role** | **Communication Channel** | **Proximity** |
|---|---|---|
| supervisor | input | temporal |
| operator | electronic | synchronous |
| collaborator | mechanical | asynchronous |
| cooperator | acoustic | |
| bystander | optic | physical |
| **Team Composition** | | following |
| | output | touching |
| $N_H = N_R$ | tactile | approaching |
| $N_H > N_R$ | acoustic | passing |
| $N_H < N_R$ | visual | avoidance |
| | | none |


https://youtu.be/2ZUn9qtG8ow

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# Solutions for These HRI Scenarios...


https://youtu.be/2ZUn9qtG8ow


https://youtu.be/hEgJOmRkAKg

Please share your solutions with your group mates.

# Comparing Two HRI Studies

- Kuz et al. and Riek et al. both investigated whether humans can more easily identify a robot's actions if it moves its arms like humans do.
  - Riek et al. found that machine-like trajectories make action identification faster.
  - Kuz et al. found that anthropomorphic trajectories and speeds make action identification easier.

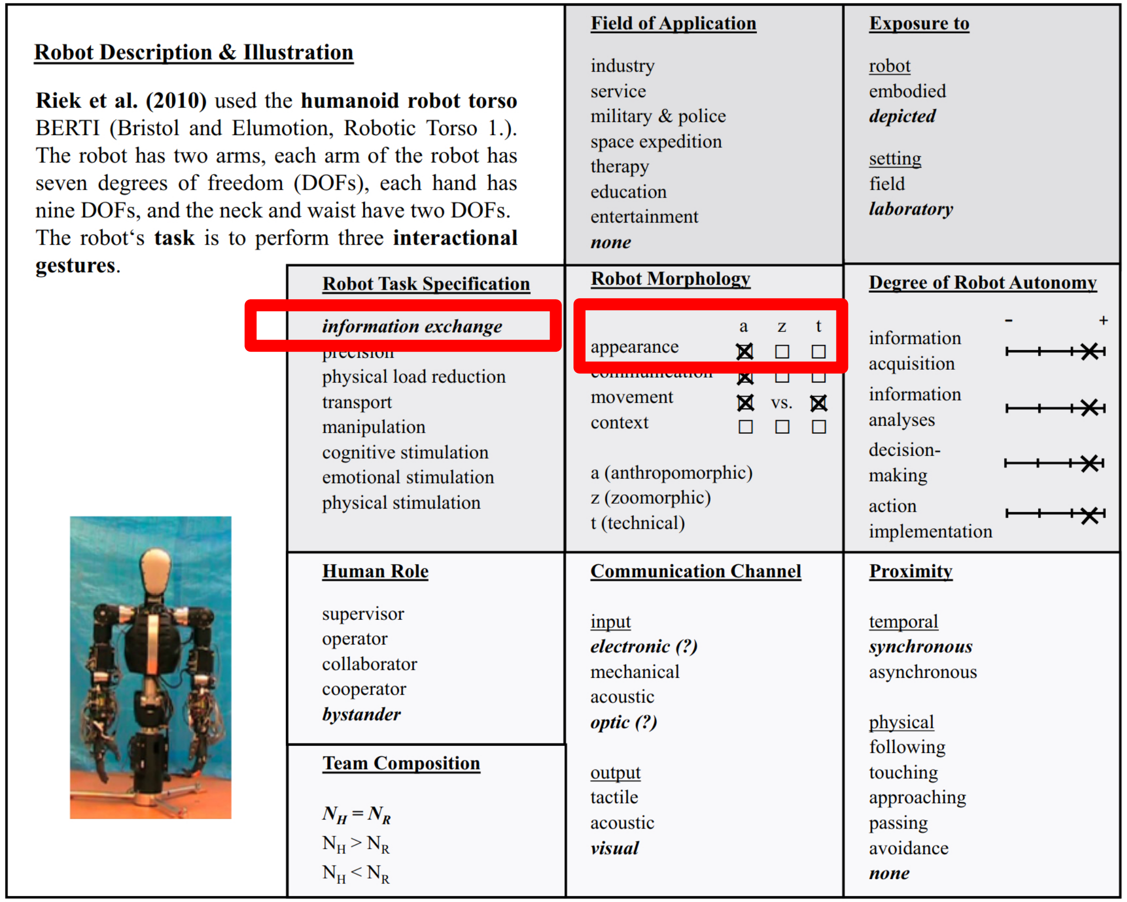
- Why are the results different?
  - To find out, let us compare the scenarios using the taxonomy.


- Kuz S, Mayer MP, Müller S, Schlick CM (2013) Using anthro-pomorphism to improve the human-machine interaction in indus-trial environments (Part I). In: International conference on digital human modeling and applications in health, safety, ergonomics and risk management. Springer, Berlin, Heidelberg, pp 76–85.

- Riek LD, Rabinowitch TC, Bremner P, Pipe AG, Fraser M, Robinson P (2010) Cooperative gestures: Effective signaling for humanoid robots. Human-Robot Interaction (HRI). In: Pro-ceedings of the 5th ACM/IEEE international conference on human-robot interaction. IEEE Press, pp 61–68.

# Comparing Two HRI Studies

An error in Fig. in the paper



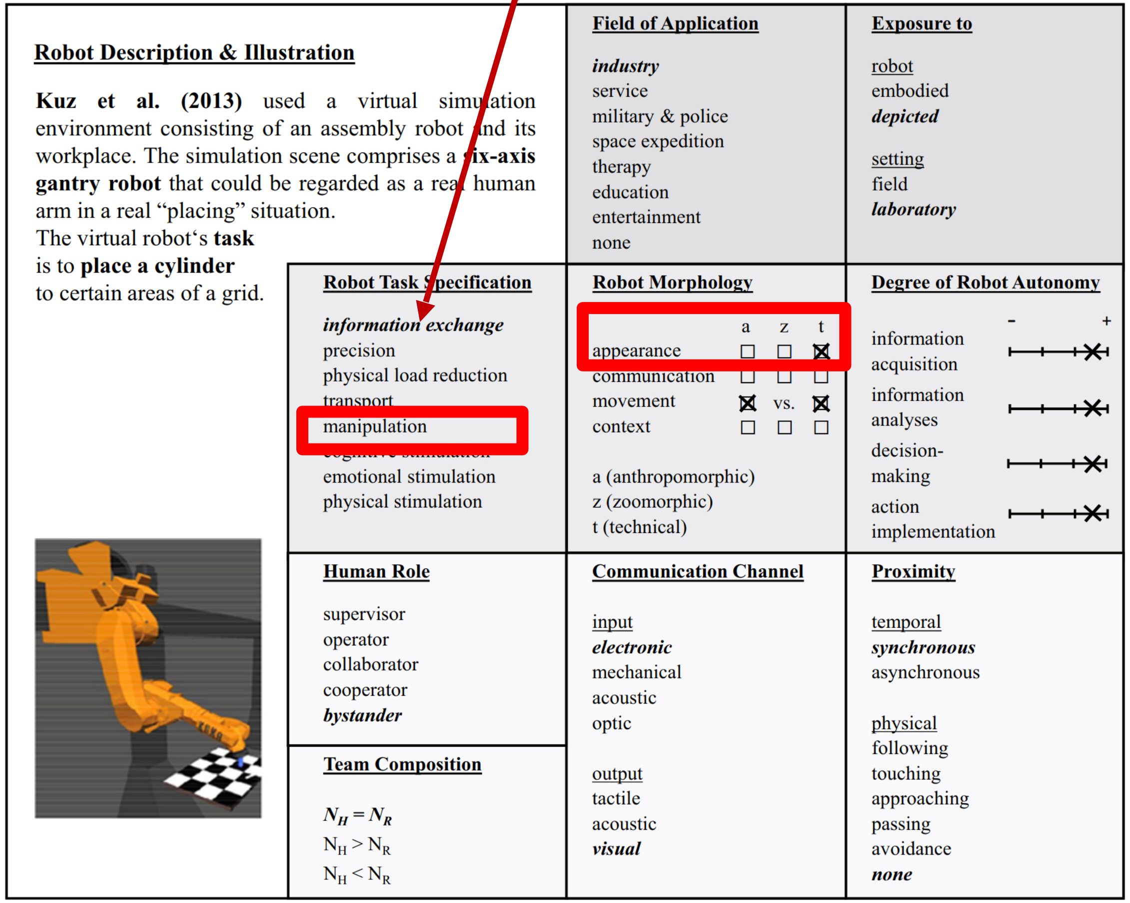




**Fig. 4 of Onnasch, L., Roesler, E. A Taxonomy to Structure and Analyze Human–Robot Interaction. *Int J of Soc Robotics* 13, 833–849 (2021).** https://doi.org/10.1007/s12369-020-00666-5

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- Why are the results different?
  - To find out, let us compare the scenarios using the taxonomy.
    - **Observation:** The scenarios are different!


- Kuz S, Mayer MP, Müller S, Schlick CM (2013) Using anthro-pomorphism to improve the human-machine interaction in indus-trial environments (Part I). In: International conference on digital human modeling and applications in health, safety, ergonomics and risk management. Springer, Berlin, Heidelberg, pp 76–85.

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# Conclusion

- In today's lecture, you learnt to:
  - Identify the elements of human-robot interaction.
    - Interaction context: Application, purpose, setting
    - Interaction partners: Humans and robots
    - Interaction itself: Type, level, frequency, duration, modalities, etc.
  - Explain the need for a taxonomy for human-robot interaction.
  - Characterize human-robot interaction scenarios using a three-layer taxonomy.
  - Apply the taxonomy to compare different human-robot interaction scenarios.

# References and Recommended Reading


1. Onnasch, L., Roesler, E. A Taxonomy to Structure and Analyze Human–Robot Interaction. *Int J of Soc Robotics* 13, 833–849 (2021). https://doi.org/10.1007/s12369-020-00666-5
   - Illustrates the taxonomy also with the example of the fictional robots C3PO and R2D2. So, take a look! ;)

2. Baraka, K., Alves-Oliveira, P., Ribeiro, T. (2020). An Extended Framework for Characterizing Social Robots. In: *Jost, et al. (Eds.)* Human Robot Interaction – Evaluation Methods and Their Standardization.
   Springer, Cham. https://doi.org/10.1007/978-3-030-42307-0_2


*[Reference 1 would be important for the exam.]*

# Next Session

- Lecture on „Nonverbal communication in humans and robots"
  - Thursday, 25.04.2024 at 9 am
  - In: B060, Grantham Allee 20, 53757 Sankt Augustin

- Reading assignment on how robots influence humans: See LEA