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Harmony
Assistive robots for healthcare

Enhancing Healthcare with Assistive Robotic Mobile Manipulation

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1. Summary

For the Harmony project, we are looking to integrate a mobile manipulation robot into the bioassay sample flow. In this deliverable, we report on the results of semi-structured interviews that we conducted at the Karolinska University Laboratory, the state of the IDMind Harmony robot prototype, and the results of the evaluation thereof at the University of Twente. Note that we will update this deliverable in a few months to include the evaluation of the prototype in the hospital, which we were not able to conduct yet due to the initial delays of this task, reported during the first review.

The goal of the interviews was to assess how the laboratory staff envisions their future work, and what role robots should take. The vision that emerged from our analysis is that of a robot which can be flexibly used for a variety of tasks within the bioassay sample flow to improve the safety (in terms of the reducing repetitive strain injuries) and productivity of staff. Robots were also believed to allow hospital staff to focus on more meaningful tasks (cognitive tasks, rather than physical labour) and turn their job roles more into supervisors of the robots. Overall, the Harmony scenarios are well positioned to fit in this vision for robots, which strengthens the use case.

To evaluate the behaviour of the IDM's Harmony robot prototype, we designed a study where we controlled for its appearance and behaviour while communicating regret, along with the violation it could commit. This study was designed under the realistic assumption that at some point the robot will make a mistake and it should be prepared to respond to them appropriately. Proper behaviour and communication modalities when dealing with social and technical errors can enhance the interaction by making it more interactive and preventing loss of trust in the system. During the pilot study, people were very eager to engage with the robot. Most participants found it funny when the robot bumped into the table, but engaged in pro-social behaviour to help it. When the robot tried to cut in the middle of a group, engaged in a conversation, people didn't move, instead, they tested its limits by moving a step back and a step closer to it.

2. Introduction

For the Harmony project, we are looking to integrate a mobile manipulation robot into the bioassay sample flow. This process currently involves unpacking, registering, and sorting bioassays, conducting bioassay-specific pre-analysis steps (e.g., centrifuging to extract blood plasma from a blood sample), and delivery of the bioassay samples to departments who carry out the bioassay (methods to determine the concentration or potency of a substance in a biological sample) or to the pre-analysis department. Introducing a robot to this process will change the work of hospital staff who are currently involved in it. Such automation may not always result positively for workers, who may be laid off or receive less wage over time (Bessen et al., 2019). Without taking the perspective of the workers into account when designing a robot, the restructuring is likely to fail (Fletcher & Webb, 2017; Welfare et al. 2019). As was found with assembly workers (Meissner et al., 2021), the acceptance of this change and the robot will similarly depend on their feeling towards technology and the expected organisational change that the robot brings.

To address this concern, we need to incorporate the needs and values of hospital staff, whose work falls within the bioassay sample flow, *in the design and positioning of the Harmony robot*. What should the future of the bioassay sample flow look like according to them? What role could a mobile manipulation robot play in this process? And how can we design the robot in such a way that it complements the staff members and holds their values intact? In other words, does the envisioned scenario for the Harmony robot match the needs and values of the hospital staff? To answer these questions, we carried out eight semi-structured interviews at the Karolinska University Laboratory in Sweden. We report on the results of these interviews in Section 3.

Overall, the Harmony robots are well positioned to meet the needs and values of the hospital staff working in the bioassay sample flow. In Section 4, we describe the design and capabilities of the first prototype of the IDMind Harmony robot. This robot will carry out its tasks and navigate within the hospital. Whereas traditional delivery robots generally use predefined paths in hallways that are reserved for logistic tasks (e.g., hallways underneath the hospital), the Harmony robots will not have such restrictions. Instead, they will be able to navigate different paths and environments. This will lead to human-robot interactions with people who simply happen to be there, such as patients, visitors, contractors, or hospital staff. As such, it will need to adhere to societal norms and values (Mutlu & Forlizzi, 2008). For instance, whilst navigating the hospital hallways, the robot may encounter social situations such as people blocking its way or wanting to interact with it. These situations need to be resolved quickly and in an acceptable manner so that the robot can carry out its task; assisting in the pre-analysis phase of bioassay samples processing and delivery.

Current robots that operate in human-centered environments have very limited interactions with the people around them. Prior to designing human-robot interaction to resolve hallway interactions, we need to have an understanding of the more common interactions that might occur. This knowledge will allow us to design deliberate robot perception-reasoning-act cycles to resolve such interactions. In Section 5, we report on a user study where we evaluate user responses to the robot. This was done in the context of getting an understanding of how the appearance of the robot influences people's response when it either makes a social or systematic error. The primary results are from a study piloted at the University of Twente. The same study will be conducted at the hospital in Almelo, the Netherlands. However, due to initial delays in this task (reported during the first year review) and the required close coordination with the hospital, we will not be able to carry out this study within the time frame of this deliverable. The study is scheduled for September (still under discussion) this year, and we will submit an updated version of this deliverable that includes the results from the study (about 2 months after).

3. Laboratory Staff's Take on the Future of the Bioassay Sample Flow and Role of Robotics

3.1 Introduction

In the Harmony use-case, we are looking to integrate a mobile manipulation robot into the bioassay sample flow. But what should the future of the bioassay sample flow look like? What role could a mobile manipulation robot play in this process? And how can we design the robot in such a way that it complements the staff members and holds their values intact? To answer these questions, we will need to understand the needs and values of users. Rather than directly asking participants on their needs and values, which can often be daunting to do so on the spot, we utilise design fiction as a tool to open up a space for discussion. Design fiction is “the deliberate use of diegetic prototypes to suspend disbelief about change” (Sterling, cited by Bosch, 2012). Diegetic prototypes refer to prototypes that exist in the world of fiction (diegesis). Design fiction consists of something that creates a story world and prototypes reflecting the story world that together create a discursive space (Dunne and Raby, 2013). The design fiction method that we will use in our study are futuristic autobiographies (FAB) (Cheon and Su, 2018). FABs, created by the researcher, are stories that take place in the future where the participant is the key character. When participants are presented with such stories, they are asked to create an autobiography that describes how the story came to be and complete the story. The completed stories are then used to open the space for a discussion on a certain topic (targeted by the researcher when creating the story).

In this section, we report on the results from semi-structured interviews, using FABs, at the Karolinska University Laboratory. With the semi-structured interviews we aim to uncover what the pre-analysis of the bioassays should look like in the future and how it, potentially, might be augmented with robotics. We aim to address the following research questions with our two studies:

> **RQ1:** How do the values of the hospital lab members intermingle with their work?
>
> **RQ2**: How might a robot augment the bioassay samples flow?

By answering these questions, we hope to get a better understanding of whether robotics can play a role in the bioassay sample flow. And if so, what aspects robots could work on and their role within the flow, and which aspects are important for the hospital staff to do themselves in order for them to carry out their responsibilities in a manner that they would like to.

3.2 Methods

3.2.1 Research Context

The Karolinska University Laboratory of the Karolinska University Hospital in Sweden participated in this study. This university hospital is one of the largest in Europe, and plays a central role in providing healthcare in the greater Stockholm area, as well as providing services to other medical facilities throughout the country. The laboratory is spread out over six separate locations within Stockholm, four of which are smaller and only carry out standard and emergency bioassays, and two are larger locations where all kinds of bioassay samples are analysed. Combined, these locations process over 26 million clinical analyses a year. While the laboratory consists of multiple departments, the pre-analytical department of the laboratory is the primary focus of this study. This department pre-processes samples for bioassay and is present at the two larger locations.

The pre-analytical department already features a significant amount of automation to facilitate pre-processing samples on both locations. In 2019, they held a pilot study with a collaborative robot which can scan and sort a variety of samples. While the study ended, this robot is now permanently embedded in their bioassay sample flow in both sites. Additionally, the department has an industrial robot (behind a fence) that opens the bioassay sample carriers from the pneumatic tube system that is installed within the hospital. This tube system is the primary method for transporting bioassay samples coming from within the hospital to the pre-analytical department.

3.2.2 Participants

For the contextual inquiry, two staff members showed the current state of the bioassay sample flow. Afterwards, we conducted eight semi-structured interviews with hospital staff involved in the process. Detailed information about the participants can be seen in Table 1. Participants were recruited by the hospital itself, taking special care to include a wide range of occupations of those involved in processing or analysing bioassay samples. *Table 1.* Detailed information of our participants.

ID	*Position*	*Experience*
SSI1	Assistant Nurse	3 years
SSI2	Assistant Nurse	2 years
SSI3	Laboratory Assistant	7 years
SSI4	Assistant Nurse	20 years

SSI5	Coordinator	8 years
SSI6	Head Chemist and Manager	19 years
SSI7	Chemist	30+ years
SSI8	Biomedical Analyst	15 years

3.2.3 Procedure

Participants were initially blind to the goal of the interview, and were informed during the debriefing. After signing the informed consent form, consent for recording the interview, and the introduction, we discussed up to six futuristic autobiographical stories with each participant. We encouraged the participants to use their imagination, think creatively, and that there was no right or wrong answer. Once the participant came up with a narrative related to the story, we further probed and asked the participant to elaborate. The interviews were held in English. Each interview took around 60 minutes. For those who consented to the interview being recorded, we automatically transcribed the interviews verbatim using Amberscript[1] and manually checked each of them afterwards. For those who did not consent to the audio-recording, we only took notes on what they said.

The stories that we constructed can be seen in Appendix A. The objective of the FABs was to elicit a discussion from our participants on the future of their lab and the bioassay sample flow. At the start of the interview, the first four stories did not mention robots, in order for us to understand how the participants foresee their future lab. These stories were designed to understand what they enjoy most in their work, current needs that they would like to have solved, dangerous situations that might occur, and how the department could improve on handling future pandemics. After discussing these stories, we moved to two robot-centered stories, in order to assess whether robotics could play a role in the participants' lab. These stories related to the envisioned role of robots in the lab, and their anticipated collaboration with robots. To further stimulate the participant's imagination, which can sometimes be difficult using FABs (Cheon and Su, 2018), we changed the autobiographical nature of the stories not to be about the participant, but about the participant's future self. The stories were framed such that this future self is talking to the participant. This way, we sought to make it clear that the participants' current knowledge and experience are changed in the future, in a way that only their own imagination can describe.

[1] https://www.amberscript.com/

3.2.4 Analysis

We analysed the transcripts through thematic analysis (Braun & Clarke, 2006). This involved two researchers (the interviewers) who were familiar with the data, generated initial codes, generated themes, and finally reviewed, defined, and named themes together. For the coding of the transcripts, we adopted an inductive approach, rather than trying to fit the data using a predefined coding scheme. The stories that the participants come up with are not necessarily realistic, so we have to look beyond what they literally mention. We therefore viewed the data within a contextualist framework, meaning that we "acknowledge the ways individuals make meaning of their experience, and, in turn, the ways the broader social context impinges on those meanings, while retaining focus on the material and other limits of 'reality'" (pp. 81, Braun & Clarke, 2006).

3.3 Results

The following themes were identified by the researchers through the thematic analysis:

3.3.1 Theme 1: Need for flexibility to enable adaptation to process changes in the bioassay sample flow.

Every pandemic will be different and will require adaptations to the bioassay sample flow. Taking the current COVID pandemic as an example, participants communicated feelings of uncertainty regarding the handling of COVID bioassay samples, as its potential degree of danger was unclear. Furthermore, to manage the increase in workload that occurred throughout the bioassay sample flow, additional staff had to jump in or be newly hired. Because not all of these new personnel had sufficient knowledge of the bioassay flow, more incidents occurred. For example, the lid of the samples was not always closed properly, posing a risk to release COVID aerosols when unpacking such samples. The COVID bioassay samples also required adaptations in the bioassay sample flow itself. The new bioassay samples were difficult to process due to clotting that the instruments could not handle.

The inflexibility of IT systems was also frequently mentioned by participants as a source of frustration and additional work. Departments who are involved in the bioassay sample flow, both inside and outside the hospital, often use different software systems that are not connected to each other and require different inputs. As a result, the staff needs to manually insert electronic forms from one system to another, or need to find workarounds. For instance, research on COVID bioassay samples was also made more difficult because of the need to use standardised electronic forms that could not be altered. As a workaround, researchers would verbally convey the additional information on how to process the samples for a certain study, increasing workload and the chance for human errors.

Lastly, the workload of staff is subject to change. The transportation of the bioassay samples to the pre-analytical department can cause a sudden influx of samples, which need to be processed immediately, when traffic is busy in the area surrounding the hospital. As mentioned earlier, the workload was largely increased by the COVID pandemic, but it also fluctuates naturally throughout the week. It is relatively quiet on Mondays and Fridays, because fewer people get tested on those days. The fluctuations in the workload may result in staff working late, and can also lead to bottlenecks in the bioassay sample flow, when not enough staff is available. This can be problematic when there are many samples coming in that are put on ice, which need to be handled quickly, or samples that need to be analysed immediately (emergency samples).

3.3.2. Theme 2: Robots are envisioned to increase well-being of staff

The tasks carried out by the staff in the pre-analytical department are not without risk to their health. All participants talked about injuries caused by exposure to ergonomic risk factors associated with highly repetitive tasks and heavy labour. Specific tasks that were mentioned included the unpacking of the boxes containing the bioassay samples, and pushing a heavy trolley containing bioassay samples that need to be delivered to other departments within the hospital. These tasks can cause injuries with the wrists, back, shoulders, or to the feet when standing for too long.

Another health risk that was often mentioned is the possibility of coming into contact with the contents of the bioassay samples due to spillage. Depending on the contents of the sample, different procedures need to be followed. For instance, the room needs to be cleared in case the sample contains aerosols.

When envisioning the future, participants generally wanted technology that could aid them or take over tasks that pose a risk to their health. Technology may be able to detect any leaking bioassay samples, intervene, and prevent exposure. The repetitive or physically demanding tasks were also frequently mentioned as tasks where technology could help. The participants mentioned that technology such as robots are better suited for these tasks, because they are faster and perform more consistently at these tasks. As such, technology could increase productivity, reduce health risks to staff, and reduce human errors by taking over such tasks.

3.3.3. Theme 3: Robot are envisioned to change their work to automation operators

Participants mentioned that they enjoy working with their colleagues, the variety of their tasks, and solving problems. On the other hand they described the manual labour that they have to do, such as unpacking boxes or distributing bioassay samples within the hospital, as tasks that are necessary, but not very enjoyable. Instead, they would rather focus on tasks that are more meaningful, and for which they are actually trained to do. From their point of view, robots could help them by taking over such tasks, allowing them to focus on more meaningful ones.

When envisioning the future, the participants described that much of the bioassay sample flow would be automated, and their work would be transformed into automation operators. They would take care of the machines, process the odd samples that the machines are unable to handle, and solve any problems within the flow. In their view, machines would break down every now and then, which halts the bioassay sample flow and would need to be fixed as soon as possible. Machines would also not be able to process all types of samples, as there would always be non-standard samples that require a human to process it. As automation operators, they would then still be in control and responsible for the bioassay sample flow.

3.4 Discussion and Conclusion

The vision that emerges from our analysis is that of a robot which can be flexibly used for a variety of tasks within the bioassay sample flow to improve the safety and productivity of staff, and to allow them to focus on more meaningful (cognitive) tasks and supervise the robots. In general, participants seemed to have a positive attitude towards automation. Not only could more automation of the bioassay sample flow be a way for them to focus on more meaningful tasks, it could also increase the productivity of the lab, help with coping with the increasing workload, and reduce tasks that pose a risk to their health. More automation would change their work, in a positive way, where their role transforms into automation operators, focusing on more cognitively demanding tasks. These are tasks that they are trained for and are perceived as being meaningful. Examples would be sorting out any bioassay samples that cannot be processed through the standard bioassay sample flow (e.g., samples with incorrect or missing information), or monitoring the various machines and resolving any problems with them.

One aspect of the work of the participants that could be further improved is their ability to adapt to any changes in the bioassay sample flow. Current generation automation is often highly efficient at processing standardised input, which also makes them inflexible to any deviations in input or in changes to the process itself. The demand for labour also changes during the day, weeks, months, or as a result of external events such as a pandemic. This can create bottlenecks in the bioassay sample flow that demands prioritisation of staff to be resolved. To improve the ability of staff to handle any changes in the bioassay sample flow, or increases in demand for labour at certain stages, a more general purpose robot could be beneficial. Such a robot would need to have the hardware that can be used for more than one task within the bioassay sample flow, and be programmable by staff to cope and adapt to new tasks, or changes in an existing task.

Looking beyond the near future of the pre-analytics lab, and beyond the scope of this study, participants were envisioning a world where the bioassay sample flow would be much shorter and centralised. Samples would no longer be transported between all the departments involved, but instead be analysed in close proximity of the patient. For instance through lab-on-a-chip-like solutions, where a bioassay sample is taken and immediately analysed by the same machine. This could improve throughput times, reduce human error by reducing the number of instances where human error can occur, and improving safety by reducing the number of people who are at risk when handling potentially dangerous samples.

4. IDMind's Harmony Robot Prototype

4.1 Prototype requirements and design rationale

IDM's Harmony robot is modular and easily adaptable to different tasks and environments (Figure 1), designed with features based on the requirements of the envisioned scenarios. The morphology for a mobile navigation solution, using IDM's mobile platforms (differential or omnidirectional), includes a robotic arm for manipulation of small objects from pick-up and drop-off regions to storage within the robot, which can improve the bioassay sample flow by performing tasks that are repetitive and physically demanding for the staff. It will also be able to perform the delivery of the samples and other ocasional on-demand deliveries around the hospital, saving time and allowing the staff to focus on other tasks. To respond to the requirements that have been identified regarding the conditions that samples need to be preserved, the design includes the embodiment of multiple modules of thermal-isolated storages for different purposes and objects that can substitute or accommodate the currently used bags and boxes.

Safety and ethical measures are also being taken into account by creating a secure system so the unlocking of a specific storage can only be done by the intended member of staff (card, app, etc.). Furthermore, the introduction of a touchscreen interface, LEDs, and sounds will act as human-robot interaction (HRI), communication of tasks, and intention features, that will allow the staff members to connect and operate the robot, but also for it to interact - and be perceived positively - with anyone who may cross its path (patients, visitors, etc).

Figure 1 - IDM's Harmony robot configurations

4.2 Current design of the IDMind Harmony robot prototype

IDM's Harmony Robot design contemplates many aspects related to functionality, usability, aesthetics, communication, human-robot interaction, safety, and ethics. Its modular nature promotes versatility and adaptability to perform different tasks and navigate a wide range of environments. It includes:

- IDM's Mobile platform (omnidirectional/differential);
- Three thermal isolated storages spaces;
- Single robotic arm for manipulation of small objects;
- Multiple modalities of interaction/communication;

Having considered the requirements for the manipulation of objects (eg. standard table height 800 mm), Human-Robot Interaction (Figure 2), safety, and aesthetics, the general specifications are:

- Max footprint: 1400 x 600 x 600 mm
- Max velocity: 1.8 m/s
- Max weight (predicted): 60 kg
- Automatic locking system (card, app, etc)
- Power autonomy estimated: 4 hours
- Payload : 80 kg

Figure 2 - Demonstrative setup for HRI and manipulation of objects of IDM's Harmony robot

5. Assessing User Responses to the Robot Prototype

5.1 Introduction

The main objective of this study is to inform D8.1 which consists of evaluating how users respond to the Harmony robot prototype.

When a robot is deployed into any environment it will make mistakes or enact behaviours that can be perceived as mistakes (behaviours considered out of the social norms). When a robot makes a mistake around stakeholders, the trust they attribute to the robot is in danger of decreasing (Salem, et al., 2015). To maintain an appropriate level of trust, the robot should be equipped with behaviours to help it navigate these mistakes in a prosocial and acceptable manner. There's research in the human-robot interaction field that investigates trust repair after a trust violation; some strategies are: expressing regret, apologising, and offering an explanation of the mistake (Baker et al., 2018; Kox et al., 2021; Wang et al., 2018). In the case of the Harmony robot, it would be difficult for it to apologise since we are considering not using semantic speech due to the expectations that it introduces. Meaning that it would have to rely on non-semantic speech which can make clear communication with the users more difficult but it has been used before successfully with other robots (e.g. Cozmo). Because of the speech limitation, we will use the robot's appearance, and behaviour to communicate regret. While there's not a lot of research on the body language used when a person expresses regret or guilt, we can look at how animators portray these feelings with robots (e.g. R2D2, a robot from Star Wars) or other non-humanoid characters with none to limited speech (e.g. Groot, a sentient tree from Guardians of the Galaxy). These robots are successfully able to convey a lot of emotions, elicit empathy, and communicate regret by using their body language and non-semantic speech.

Eliciting empathy when showing regret is important because according to studies in social psychology, when a person commits a violation towards another and tries to repair the relationship, the offended individual will be more willing to forgive the violation if they feel empathy towards the offender. In HRI, several studies have found that people can feel empathy towards a robot, e.g. when it is being abused or it makes mistakes and shows regret (Hamacher et al., 2016; Rosenthal-von der Pütten et al., 2013, 2014; Tan et al., 2018). Hence, successfully evoking empathy towards the robot when it commits a violation could help increase the chances of it being forgiven and repairing the trust between the user and the robot.

A robot who has cute attributes could elicit more empathy and impact its forgiveness. There seems to be a relationship between empathy and cuteness. For example, depending on how cute an animal is, the less or more willing a person might be to eat it. This relationship between harm and cuteness seems to be mediated by the level of empathy a person feels towards the animal (Zickfeld, 2018). Also, in a study on AI assistants, researchers found that people seemed to tolerate non-severe mistakes more often when done by a "cute" looking AI assistant (Lv, 2021). While the objective of this deliverable is not to inform the appearance of the robot, it will inform D8.2, which reports on the appearance design.

There are different types of failures that a robot can commit. In Leimin Tian and Sharon Oviatt's taxonomy of social errors in human-robot interaction, they made a distinction between performance and social errors (Tian and Oviatt, 2021). They differentiated these errors by having a user-centered approach; the social errors are committed when the robot breaks a social norm and the performance error deteriorates its performance on its tasks and dilutes the user's perception of its intelligence and/or competence.

In short, a robot will most certainly make mistakes (whether they are social or performance related) and it needs to respond appropriately. As the level of empathy that individuals feel towards their offenders influences their ability to forgive, if a robot elicits empathy then its chances of being forgiven will increase. Furthermore, cuteness seems to evoke more empathy from the stakeholders, hence, the use of "cute" behaviours and appearance can increase empathy and the chances of the violation to be forgiven.

In order to investigate the current gap of research on the role of cuteness on the empathy and forgiveness people feel towards the HARMONY robot when it commits a performance and a social violation, we aim to answer the following research questions (RQs):

> **RQ1:** How does the use of "cute behaviours" (movement, sounds, and eye expressions) impact the empathy and forgiveness towards the HARMONY robot when it commits a violation?
>
> **RQ2:** How does the empathy and forgiveness attributed to the Harmony robot differ upon witnessing a performance or a social violation?

To address these research questions, we designed a 2 x 2 between-experiment where we manipulated the HARMONY robot's **cuteness** (by the use of *cute* x *non-cute appearance and behaviour*) and the **type of violation** (*social* x *performance*). The robot will be controlled (Wizard of Oz) by a researcher while it navigates a waiting room at a hospital. Other two researchers will annotate how people react towards the robot before, during, and after the violation. After the robot's error, a researcher will approach the participant and ask them for their consent to conduct a semi-structured interview. During the interview, we will ask participants questions about the **cuteness/appearance** of the robot, their **perception of the violation**, their **empathy** towards the robot, and their **willingness to forgive** the violation during the interview. After data collection, we will use thematic analysis on the interviews to identify patterns and themes regarding their empathy and forgiveness towards the robot.

Figure 3 - Harmony Robot (Photo taken by IDMIND)

Because of previous work on the positive relationship between empathy and cuteness (Zickfeld, 2018) and empathy and forgiveness (Aragon, 2016), we derived the following hypothesis:

H1: Participants will experience more forgiveness and empathy towards the robot when it uses cute behaviours and eye expressions to show regret.

A second hypothesis was derived from previous research on robot errors in the healthcare environment where the robot will perform the errors. In Manuel Giuliani et al.'s paper (2015), they compared how people reacted through social or technical errors. In their research they found behavioural differences, although, since their research was to systematically review videos where these mistakes happened, they didn't have access to participants to interview and compare these two types of errors. Because the robot will be placed in a healthcare environment, we believe that technical errors might be more relevant than social ones.

H2: Participants will experience more forgiveness and empathy towards the robot when it commits the social mistake.

In the following sections of this paper, we will introduce the methodology of our experiment, then, we will present the results of a pilot test that was run at the University of Twente. The results from the hospital experiment will be presented later on, as the experiment is scheduled to happen in July. The preliminary results section will include the results from the pilot.

5.2 Methods

5.2.1 Experimental Design

In order to expand the research on the effect of robot trust violations in the wild, we designed a 2 x 2 factorial between-subjects experiment where we manipulate the robot's cuteness and the type of violation it performed.

Because of previous research on the effect of cuteness and tolerance of mistakes on AI agents, our first independent variable (IV) is the robot's **cuteness**. In previous studies, researchers found that big round eyes are perceived as cute, hence, we chose to manipulate the robot's eyes, expressions, and behaviours to increase its cuteness. In this study we will manipulate cuteness in the following way:

- **Cute appearance and behaviour (Figure 4):** will consist of the robot having big round eyes. After the robot's "mistake", it will move away from the participants, while appearing sad, and making high pitch sounds to show regret about its action.
- **Non-cute appearance and behaviour (Figure 5):** will consist of the robot having smaller squared eyes. After the robot's "mistake", it will move back to its original position.

Figure 4 - Cute appearance and behaviour showing regret

Figure 5 - Non-cute appearance

The second IV is the **violation** the robot will perform. We decided to choose one *social* and one p*erformance violation.*

The *performance violation* we chose for the robot is dropping something and disturbing people around. This one was selected due to the real possibility of happening. For the *social violation*, the robot violating someone's personal space was selected based on the prior work by Jered Vroon and Michiel Joosse, who both have done extent work on using the invasion of personal space as a social violation and studied it limits, and how people react to it on different conditions (Vroon, 2017, 2018; Sandar, 2012; Joosse, 2014).

During the study, we manipulated the violations in the following manner:

- **Social violation:**
    - The robot will approach a participant seated in a specific chair and remain at their side.
    - The robot will try to move through a group of people having a conversation instead of going around them.
- **Performance violation:**
    - The robot will drop a tray with items on top.
    - The robot will bump into a table and will drop an empty water bottle from it.

5.2.2 Participants

In the pilot, we will run the study at the lobby of the Hal B building at the University of Twente. We expect the participants to be either students or university staff members. We plan to recruit 40 participants (5 per condition).

During the study at the Almelo Hospital, the Harmony robot will be driven around a room where the population will not be at risk. Because we plan to run this study in the wild, we will be constrained when someone takes a seat on a specific chair to start the experiment. We expect 80 individuals (10 per condition) to participate in the study over the course of five days. In order to keep a diverse participant pool researcher's will actively choose to start the study with different types of population. Also, in order to not create an obstacle for workers and people with a mobility impairment, researchers will only run experiments when it is safe to do so.. Depending on the participant's preferences, the interview could be conducted in either English or Dutch.

The current study and all its materials will be approved by the Ethics Committee Computer & Information Science (EC-CIS) at the University of Twente. Reference number: RP 2022-143.

5.2.3 Materials

We will be using IDM’s prototype for the HARMONY robot during the studies. A researcher will discreetly use a Logitech Wireless Gamepad F710 controller to control the robot's movements and behaviours and a wireless speaker will be added inside of the robot. We will also use a phone as a voice recording device (only used if the participant consents to the study and to be recorded), a Logitech wireless keyboard to change the face of the robot, a foldable tall round table (as seen in Figure 6), some IEEE magazines to put on the table, and a notebook to write down our annotations.

During the study at the hospital, the robot will also be carrying a cafeteria tray with an empty aluminium water bottle on top of it. The addition of the tray is still in development.

5.2.4 Experimental Setup

The pilot will take place at the lobby of the Hal B building at the University of Twente. We will place a sign stating that a robot testing is taking place, that it is safe, and our contact information (as seen in Appendix C). Depending on the violation the robot will make, the experiment will start when someone sits on a large couch, walks by the robot, or there’s a group of people having a conversation together while standing up. If there's someone sitting on the couch, the robot will either stand very close to them, or will stay at a socially acceptable distance but will bump into the table which will make a water bottle fall from it. The last manipulation of walking through a group of people will be triggered once we locate such a group.

Figure 6 - Setup for pilot study

The location of the experiment at the hospital is still being discussed. Although, the rest of the experiment will run in the same way as the pilot, together with the placement of a sign stating that a robot testing is taking place, that it is safe, and our contact information.

5.2.5 Procedure

Once a participant sits on a specific chair or couch spot, the study will begin. The HARMONY robot will navigate the room where the participant is and it will either be equipped with **cute or not cute** appearance and behaviours. The researcher in charge of controlling the robot will be discreetly using the controller and will have full view of the interaction. Another researcher will sit in front of the participant and will start making annotations once the robot enters the room.

Once the robot enters the room it will perform either one of the **performance or social violations**. The researcher tasked with the annotations will continue to do so until the interaction seems to be concluded (e.g. when the person goes away or ignores the robot). During the pilot study, the violation of dropping items on the robot’s tray was not used.

Once the interaction is over, a researcher will approach the participant and ask them to participate in an interview. If the person **does not** wish to participate, we won't use their annotated data. If they do consent, we will ask them for permission to voice record the interview and start the **semi-structured interview (Appendix B)**. If they do not wish to be recorded, we will take notes in a notebook.

After the interview we will ask the participant for their demographic information and inform them that the robot was being controlled by someone the whole time. We will also give them our contact information in case they have any questions.

5.2.6 Measures

In order to answer our research questions we have the following dependent variables: empathy and forgiveness. We will also include *two manipulation checks* to make sure the cuteness and violations are perceived as different manipulations.

Our dependent variables will be measured during the interview. The first interview questions will start by focusing on what the participants thought of the violation, if they forgive the violation and would be willing to be around it and how much empathy they felt towards the robot if it was being replaced. Then the questions will change to be regarding how they describe the appearance of the HARMONY robot and how they felt when the robot was roaming the room.

Other data that we are interested in annotating is in regards to how people move and behave around the robot before, during, and after the violation, along with other obstacles and interactions it might encounter. The specific themes we are interested in noting down are the *participant's* ***most salient*** *body movements, facial expressions, and verbal reactions.*

5.2.7 Analysis

Because we will use semi-structured interviews as our method to collect the qualitative data, we will use *grounded theory analysis* as created by Barney Glaser and Anselm Strauss. This process is iterative and will help us inform future studies (Walker and Myrick, 2006).

5.3 Pilot's Results

We are still running the pilot study at the University and currently, we have 9 participants. They are all male students and their age ranged from 18 to 24 (*M=21*). Different behaviours and reactions to the robot's mistakes were identified. *Please note that these are just the initial findings as we are still running the study.* Because this study is still ongoing, we cannot answer our research questions just yet. After transcribing the interviews, we noted the more salient information that is related to our research questions which can give us an initial idea of what are the participants' perceptions of the prototype's behaviour.

Personal space invasion x Cute appearance *(1 participant)*: During the interaction, the participant ignored the robot and focused on his phone. During the interview, he mentioned that he prefers to ignore the robot and that it could be annoying if it gets too close to people. When asked about his trust in the ability of the robot to complete a task, he said "So maybe it does not recognize objects very well. So then no, in that case, I won't trust it's very well because it will just keep bumping into people. Maybe”. Hence, there was a decrease in the robot’s trust after witnessing the violation. He also often mentioned that he was confused about the actual task of the robot. There was no show of empathy as he did not mind if the robot had to be replaced or destroyed.

Bump into table x Cute appearance *(3 participants)*: All of these participants tried to help the robot by moving the water bottle away from the corner of the table and moving the table out of its way. Two of these participants walked together, they laughed and exclaimed that the robot was trying to kill itself when it bumped into the table, while the other participant looked very puzzled when the robot bumped into the table. The participants still trusted the robot to complete its tasks after the violation.

Cut through a group of people x Cute appearance. *(2 participants)* When the robot approached the group, the participants didn’t move out of the way and proceeded to inspect it. These participants seemed very eager to interact with the robot and mentioned that they would still trust the robot to complete its tasks, although one of them expressed privacy concerns regarding trust and asked about the camara in the robot’s head. This last participant also regarded privacy violations more concerning than bumping into things.

Cut through a group of people x Non-cute appearance. *(3 participants)* These participants did not let the robot pass through the middle of the group. They stayed in their positions and proceeded to inspect the robot and test its capabilities (saying hello and waving their hands on the robot’s face). Again, they also seemed very eager to interact with the robot. During the interview they described the robot as Wall-E like but would fit into a hospital, they did not mind if the robot was to be destroyed or replaced.

Overall, all participants could imagine the robot being placed in a hospital. They mentioned that it looked very hospital-like and that since hospitals already have different types of equipment, it doesn’t look out of place. Several participants mentioned that it looked like Wall-E or out of the movie and that it looked kind, nice, and adorable. Three participants compared it to a server robot in restaurants, two mentioned that it looked like a cleaning robot, or a robot to inform people about the building.

5.3.2 Other interesting findings during the pilot study

While we set up in the lobby or transported the robot through the University, a lot of people approached the robot. When they did, they engaged in the following behaviours:

- Cute condition while parked (only blinking)
    - They approached the robot and waved at its face (as if they were expecting an interaction).

  - Groups of people talked about the robot excitedly.
  - When it approached a person for the invasion of personal space condition, other people started to laugh about it.
  - Called the robot pretty, nice, and cute.
  - Took pictures.
  - Tapped it.
  - Hugged the robot.
- Cute condition while moving
  - People said hello and bye to the robot.
  - Stopped in front of it to inspect it.
  - Most people looked very excited about it.
  - People looked at it and seemed curious.
  - When moving the robot in a hallway to get to the lobby, some people hesitated to walk besides it.
- Sad while moving
  - People walking by wondered why it was sad (“Awwww, why is it sad?”)
  - People wondered if it was a support robot.

5.4 Results Hospital

T.b.d.

5.5 Preliminary Discussion

While we are still conducting the pilot test at the University of Twente, we have already found interesting responses towards the robot and its violations. Since all of the participants so far are students, and the location of the lobby where the pilot is taking place is in a building where technical courses are taught, we saw a lot of enthusiasm from people walking by the robot and participants themselves. People often got close to the robot to inspect it, greeted the robot, and there were two different instances where someone hugged the robot while we were setting up. Even when the robot made a violation, people seemed to enjoy it and joked around. This enthusiasm might not translate to a hospital environment which has a different set of social norms.

When we asked participants about their feelings if the robot had to be replaced or destroyed, they did not seem to care about it. Although, two participants who interacted with the cute robot bumping into the table did mention that it would be a waste if it got destroyed as it could be donated somewhere else. To really conclude if there is an increase or decrease of empathy and forgiveness depending on the appearance and violation of the robot, we need more participants. Although, because we are still running the study, this will be added to the updated deliverable after the study is over. The updated deliverable will also include the results from the hospital study.

The inclusion of the pilot test is informing us of initial responses towards the Harmony robot prototype and how people behave when it makes a violation. While the pilot test is not over, we have learned about items we need to improve on for the study at the hospital. We noticed that the current design of the non-cute appearance condition is not obvious enough. To improve on this, we might use a new set of eyes similar to the ones shown in Figure 7 for future studies. These eyes would give us a greater contrast between the cute and non-cute condition.

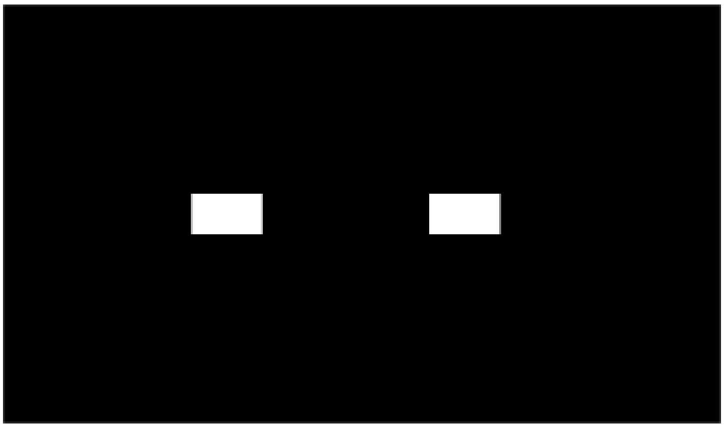

Figure 7 - Non-cute eye expression for future studies

6. Conclusions

The interviews with the laboratory staff members show that the Harmony robots are well positioned to address their needs and wishes. The ability for the robot to be mobile, carry out a variety of manipulations, and be taught new tasks, can allow the Harmony robot to be used more flexibly than current solutions. Moreover, the staff members envisioned that robots could increase their well-being by taking over tasks that are physically demanding. Instead, they envision themselves doing more cognitively demanding tasks: tasks for which they were trained for, and consider meaningful. The tasks that the Harmony robots can perform align with staff's current expectations for it. To improve the generalisability of the results, we aim to conduct similar interviews at different hospitals (university hospitals compared to regional hospitals) in different countries (Switzerland and the Netherlands).

The pilot study gave us insight into how people respond to the Harmony robot prototype when it makes different mistakes in a "real" environment. Although, these reactions, such as the enthusiasm and even humour by the participants and bystanders, may be bound to the social context of the environment we are conducting the pilot in (at an University lobby) and the demography of the participants (students). These behaviours might differ when the robot is located in a hospital and interacts with other audiences, even within the hospital (e.g. staff, visitors, patients). For future studies, we aim to explore this further, along with a longer-term study to reduce the novelty effect, which is especially important when studying the robot's behaviour when engaging with lab members.

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Appendix A. The Futuristic Autobiographical Stories

Story #1: Fun aspect of their job

Goal: to uncover what aspects participants enjoy most about their work.

Story: In a couple of years from now, an electric car drives you back home. You hurry inside, take off your shoes, and start recording your daily log entry. Today was a particularly fun day at work. Why can't every day be like this? You quickly finish recording, because you can't wait to tell your loved one about your day. What does your log say?

Story #2: Current needs

Goal: to uncover what problems participants would like to have solved and why.

Story: It's Friday in a couple of years from now and you are having dinner with a loved one. The food is still steaming, as it is quite hot, but you can already smell the rosemary. You have to wait a bit before you can start eating. One of your colleagues, who started working in the lab two months ago, comes to mind. He was constantly complaining about work today. It annoyed you, and you believe that the complaining was unjustified. A couple of years back, it was much harder... You start to appreciate the technology that was introduced to your lab then. It sure made your work a lot easier and enjoyable. What was your colleague complaining about?

Story #3: Dangerous situations

Goal: Uncover what aspects of their work might have severe consequences to them, others, or their work, and how they dealt with it.

Story: In a couple of years from now, one of your colleagues comes in a bit late. He does the same work you do in the lab. You notice that he looks really tired. This is not strange, as he became a father for the second time and now has to take care of two babies. At two o'clock in the afternoon, you see your colleague do something that could put a patient in serious danger. Luckily you noticed it quickly and intervened just in time. What did your colleague do? Why did it lead to a dangerous situation?

Story #4: Dealing with Future Pandemics

Goal: what changes would the participant like to see for facing the next pandemic?

Story: You watch the news and hear that the pandemic is finally over. Over the last couple of years, only a few cases have been reported. Nevertheless, your government issues a call to all hospitals to innovate in order to better handle future pandemics. The head of your department organises a workshop where you and some of your colleagues brainstorm how technology could make your lab better at handling a future pandemic. Together you come up with several ideas on how to improve your lab with technology. Your idea in particular seems promising, which makes you feel proud. This could really make a difference! What technology did you suggest and what will it do? What aspect of your idea made it such a promising idea?

Story #5: The Role of Robots in the Lab

Goal: to uncover tasks participants would rather delegate to a robot, and what would expect of robots.

Story: In the future, robots started to play a role in your lab. At first, you felt awkward about sharing your workplace with two robots. They are now doing a task that you had to do previously. It took some time to accept them as your work colleagues. Now, you have no problem working with robots at all. They freed up some of your time, and you can now spend more time on tasks that are important to you. What specific task(s) is given to these robots?

Story #6: Robot Communication

Goal: Uncover participant expectations regarding their interaction with the robot.

Story: One summer's day, somewhere in the future, one of the newly purchased robots finds something surprising. It is not programmed to deal with this situation and it needs your help. Once there, you quickly spot the issue. By collaborating with the robot you managed to deal with the situation. What was the situation about? How did the robot signal you for help? And how did it communicate with you when you were collaborating to deal with the situation?

Appendix B. Semi-structured Interview Questions

Questions regarding the violation:

1. What did you think about the robot's actions?
2. Would you still want to interact with the robot?
3. Would you feel bad if the robot had to be replaced or destroyed?
4. Would you still trust the robot to complete its tasks?

Quotations regarding the robot:

1. How would you describe the robot's looks?
2. When it entered the room, what did you think about its tasks?
3. How do you feel about a robot being in a hospital?

Demographic Questions:

1. What is your age?
2. Where are you from?
3. Are you a student or an employee?

Appendix C. Pilot Test Poster Sign