# Exploring User Interactions with the Articulated Head in Different Settings

*An HRI study*

*Master's Thesis*

*Engineering Psychology*


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BREAKING NEW GROUND
AALBORG UNIVERSITY

AALBORG UNIVERSITET
STUDENTERRAPPORT

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**Titel:**
Exploring User Interactions with the Articulated Head in Different Settings.

**Projekt:**
Kandidatafhandling (Master's Thesis)

**Projektperiode:**
4. februar, 2019 - 6. juni, 2019

**Projektgruppe:**
19gr1080

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**Vejleder:**
Dr. Elizabeth Jochum
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**Sidetal:** 81
**Appendiks:** 101
**Afsluttet:** Den 06. juni, 2019

**Synopsis:**

We worked with the robot platform called the Articulated Head (AH) to explore Human Robot Interaction (HRI). We applied a mixed method approach using scale questionnaires, ethnography, interviews and thematic analysis to understand how people interact with the AH and how they experience the robot. We conducted two grounding studies in different settings. We also conducted two main studies with similar research designs at two different settings, one in the wild and one in the lab. We compared the findings from each main study to understand to what extent results from a study in the laboratory transfer reliably to real world settings. We collected observational data of the interaction, conducted interviews before and after the interaction with the robot and got the participant to rate the robot using Godspeed questionnaires. Six design suggestions are made that would create a more convincing and engaging interaction with the Articulated Head in the context of a science museum. Our findings also suggest that the results from studies in the laboratory can reliably be transferred to real world settings to some extent when focusing on HRI, though, more studies with a greater sample size are needed. The findings will likely benefit the further development of the AH but also help define which methodological approach one can take in order to understand and predict how different settings influence HRI.

# Dansk Resumé

Dette er et speciale udarbejdet i Australien gennem afgangsprojektet på vores kandidat i Produkt- og Designpsykologi. Projektet omhandler eksplorativ undersøgelse af interaktion mellem mennesker og robotter, og om hvordan denne interaktion kan designes, så den bliver mere overbevisende og engagerende for personen, der interagerer.

Projektet er udarbejdet omkring kunstinstallationen kaldet the Articulated Head (AH) som er en social robot, der vil blive udstillet på udstillingen ved navn *Born or Built?* på Questacon - The National Science and Technology Centre i Canberra, Australien. Da AH snart vil blive flyttet fra laboratoriet og ud i en ny setting i den virkelige verden, har vi valgt i dette projekt at undersøge i hvilket omfang, resultater fra et studie udført i et kontrolleret laboratorie, kan overføres pålideligt til omgivelser i den virkelige verden. Dette ledte os frem til en endelig problemformulering som er:

***Hvad er de essentielle aspekter for at designe en overbevisende og engagerende interaktion med en social robot i et museum? Samt, I hvilket omfang kan resultater fra et studie udført i et laboratorie overføres pålideligt til omgivelser i den virkelige verden?***

For at adressere problemformuleringen har vi udført fire studier i alt, to forberedende studier og to hovedstudier. Det ene af vores forbedrende studier blev udført på Questacon, hvor vi interviewede besøgende ved *Born or Built?* udstillingen, samt anvendte walk-along metoden under deres besøg ved udstillingen. Formålet med studiet var at undersøge konteksten, hvori robotten vil blive implementeret, og få en forståelse for udstillingen, og de besøgendes oplevelse af den.
Det andet forberedende studie blev udført i laboratoriet, hvor vi testede, hvordan to forskellige positioner af basen af robotten påvirkede perceptionen af robotten. Studiet havde også til formål at give os erfaring med at styre robotten og udføre Human Robot Interaction (HRI) forsøg i laboratoriet. Fra studiet fandt vi en tendens, at basen i Profil position var at foretrække over basen i Front position.

De to hovedstudier, vi udførte, havde samme test design, men blev udført i to forskellige settings. Det ene studie blev udført i laboratoriet, mens det andet blev udført i den virkelige verden ved et event på University of Canberras campus. Vi anvendte en mixed-method tilgang, hvor vi både indsamlede testdeltagernes rating af robotten på Godspeed questionnaires, interviewede deltagerne før og efter interaktionen, samt videooptog deres interaktion med robotten. Vores sample size var for lille til at lave en statistisk analyse af den kvantitative data, så denne blev analyseret for tendenser i stedet. Den kvalitative data fra studierne blev analyseret ved anvendelse af Thematic Analysis metoden. Fra vores resultater fra de to hovedstudier, kunne vi opstille seks konkrete design forslag til at designe en overbevisende og engagerende interaktion med AH i et videnskabsmuseum. Disse forslag er: Placer basen af robotten i Profil position, brug øjenkontakt mellem robotten og brugeren til at indikere for personen, hvad robotten interagerer med; placer interaktionen

foran robotten, så brugeren står ansigt til ansigt med robotten under interaktionen; fjern den animerede hals og skulder på robottens skærm; mennesker vil røre robotten, hvis de kan - tag sikkerhedsforanstaltninger i forhold til dette og brug robottens virtuelle hoveds animationer til at indikere næste bevægelse for robotten, så brugeren nemmere er i stand til at forudsige robottens bevægelser.

Ved sammenligning af resultaterne fra studiet udført i laboratoriet og studiet udført i den virkelig verden, fandt vi mange sammenlignelige resultater, men også enkelte resultater, som vi kun fandt i den ene kontekst. I den sammenhæng vil vi nævne testdeltagernes forventninger til testen og robotten, som vi fandt til at være højere i laboratorieforsøget, og som så ud til at påvirke deltagerne til at bedømme robotten lavere, end deltagerne i studiet i den virkelige verden gjorde.

Dette projekt har været en del af et 3-årigt forskningsprojekt, der vil fortsætte efter vores afhandling. Vi mener, at resultaterne og metodologien anvendt i vores projekt kan guide videreudviklingen af AH, samt generelt gavne yderligere forskning inden for HRI i rigtige omgivelser.

# Preface

This thesis started out with a rough description of a possible Master's Thesis in an email from Dr. Elizabeth Jochum October, 2018. She invited our group to a meeting explaining the general outline of a robotics project that would be supervised by her and conducted in collaboration with Aalborg University, the University of Canberra and Questacon: The National Science and Technology Centre in Canberra, Australia. We, the authors, accepted this opportunity not knowing exactly what the project was about, other than a talking robot dubbed the Articulated Head that sprung out of an artwork by an artist called Stelarc, and with the premise that much would only be clear once we arrived in Canberra.

We arrived in Australia mid March and worked on this thesis in Canberra for 3 months, handing it in from "down under" on June 6, 2019. Over the course of the project, we utilised `www.trello.com` which is an online project management tool. We drew on Scrum project management techniques by creating a backlog, a list of tasks to do, and list when they were done. This project has definitely not been a linear journey, and the focus of the project changed many times because of it. There were many different actors involved that influenced the course of the project. We came into the project thinking we would test a robot with a fully functional attention system at Questacon's exhibition space and again in a mirrored lab setup. Many different factors contributed to this not becoming a reality.

In the end, however, we did end up conducting a study in the wild at a student event at University of Canberra with no barriers, and a similar setup in a lab setting while also managing to collect data at Questacon. Our results from these studies will benefit the future development of the Articulated Head by highlighting current issues and possible improvements in order to improve the Human Robot Interaction experience. Also, the findings might help shed light on general considerations one has to make when deciding to move out of a controlled setting and into the wild. This thesis shows a proposed method of approach for comparing findings of a HRI study between two settings.

## Reading Guide

In-text citation is made using a referencing style resembling Harvard. It consists of the authors' last name and the year of publication in brackets placed within the text. If relevant the page numbers of the citation is listed after the year of publication. Examples of citations is: "according to Lastname (2000).." or "Lastname et al. (2000) or "..(Lastname, 2000, p. 1), where "et al." is added for publications with more than three authors. An overview of all cited publications made in the report is found in Bibliography.

References to figures in the report is made with two numbers separated by a dot. The first number indicates which chapter the figure is presented in and the second number indicated the figure number in that specific chapter. An example of an reference to a figure in chapter 2, figure number 1 is: "Figure 2.1". References to sections in the report is made in the same manner, with the first number indicating the chapter and second number indicating the section number.

When references are made to the appendices, it will be made this way: "See Appendix B". Some appendices can be found in the ZIP-file accompanying this report. An overview of the content within the ZIP-file is listed in Appendix A.

If we use a quote from a participant in a conducted study, it is shown like the following:

> 01.15 P6: And he's never looking – ah well he doesn't appear to be ever looking straight forward.

The numbers refers to the time stamp in the audio or video clip. The following "P6" means it is taken from Participant 6's audio file. A reference to the video data appears similar but specifies which video it is taken from before the time stamp.

Throughout the thesis, all our references contains a hyperlink to where it references to, when read in the original PDF-format.

## Acknowledgement

First of all, we would like to thank the University of Canberra for the collaboration on this project and state our gratitude for the invitation to use the facilities and equipment at the University's Human-Centered Technology Research Center. A special thanks to Dr. Damith C. Herath, David Hinwood and James Ireland for the collaboration and technical support throughout our time at the robotics lab at University of Canberra.

Thank you to the performance artist, Stelarc, and the University of Surrey - especially Dr. Christian Kroos, whom together with Dr. Damith C. Herath, developed the first version of The Articulated Head and the continuous development of The Articulated Head 2.0. We would like to thank these three for letting us be a part of the work with the new version of the Articulated Head and sharing their work and knowledge the first version with us for this project.

The authors also wish to thank Questacon, Australia's National Science and Technology Centre for their contributions to this work.

For recognising the value in this project, and choosing to support it financially, we would like to thank IT-vest - Collaborating Universities, The Oticon Foundation, Inge Mogensen Scholarship, The Initiative Fund for Hirtshals and the Surrounding Area, Danish Tennis Fund and the Fund of Otto Mønsted.

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# Introduction 1

We live in a time where technology undoubtedly plays a big role in our everyday lives. Increasingly, humans interact with machines and AI algorithms are ever present in our social media, how they shape the news, our politics and the online information that we are subjected to, (Rahwan et al., 2019). This has spawned a new research area called machine behaviour which entails an interdisciplinary effort to study how the implementation of these technologies might affect our social interactions in everyday life and how these machines behave, (Rahwan et al., 2019). These artificially intelligent algorithms are also moving into robotics where embodied agents are inching closer to wide implementation in society.
The field of social robotics is an emerging field where the encounters with robot technologies in our every day lives might soon be very common, (Elliott, 2019), (Breazeal, 2017). As these social robots enter human's lives, the interaction with them should feel natural and seamless, (Breazeal, 2002, pp. 1–4).

Some of the first steps towards this paradigm shift can be seen in industrial robots, where collaborative robots are being placed outside previously necessary safety cages. Examples include the UR series developed by Universal Robots (`https://www.universal-robots.com/` or robots from Rethink Robotics (`https://www.rethinkrobotics.com/`), perhaps most famous their Baxter robot. A classic industrial robot can take months to implement and needs an expert to program it. These robots, by contrast, can be set up and programmed within hours. An individual with no prior training is able to train the robot to do simple tasks within a few minutes, simply by moving its arms around by hand, (Brooks, 2013). Service robots are emerging as well, which will be able to navigate complex environments autonomously and provide help with daily tasks. According to Brooks (2013), this will be a very important issue when taking the population growth into account. A much bigger part of the population will be over the age of 65 while the working population will shrink and so will the available workers to care for the elderly. Social, collaborative robots might be a great assistant in curbing this potential problem.

The field of Human Robot Interaction (HRI) is therefore important if we want to create more natural and effective interactions between humans and robots. Here, the exploration of the human interaction with robots is a key factor in understanding, designing and evaluating the robots from a user-centred point of view. If the robots are expected to be implemented in society, it is also very important to be able to test the robots in their intended environments outside of a controlled laboratory so as to implement the correct context in the development phase, (Rahwan et al., 2019).

Exploring the interaction between humans and advanced technologies such as robotics and AI is a complex multidisciplinary research field, where knowledge about both parties in the interaction is important in order to fully understand it. We need ways to measure the human experience and the ability to manipulate the technology in an iterative process that is based on sound research. The field of Engineering Psychology combines knowledge of technology and psychology to conduct research where the focus is on the user experience of technology and makes the topic of HRI highly suitable for a research project in Engineering Psychology.

This project is a collaboration between Aalborg University (AAU), University of Canberra (UC), and Questacon - The National Science and Technology Centre with their exhibition called *Born or Built?*. This exhibition creates unique opportunities for conducting HRI research outside the lab. The advantage of conducting research in a public setting like a science centre is that people naturally interact with robots in the exhibits. Many people have not directly interacted with robots before as they are not yet a common part of their everyday life. They therefore have limited knowledge of these embodied technologies and might have preconceived notions about robots and their capabilities that do not necessarily reflect reality. This makes it interesting to explore their interactions with the robots and how their experiences and interactions in different settings might affect their interaction and perception of robots.

Based on the topics presented in this introduction, an initial problem formulation is created. This initial problem formulation will be the basis for a literature review and a problem analysis that will lead to the final problem formulation.

## Initiating problem formulation

How is the human robot interaction from a human-centred point of view effected by the setting the robot is placed in, and what factors are important to consider when interpreting the interaction with the robot?

# Literature Review 2

A literature review was conducted on five different topics found to be relevant in regards to this project and to gain knowledge about the field of human robot interaction in order to further specify our problem formulations and approach in the project.

## 2.1 Public opinion on robots and AI

A large questionnaire study from 2017 investigated the public perception on robots within EU countries and used their study from 2014 as comparison (EU, 2017). The questions ranged from broad general opinions on robots to more specific e.g. How comfortable they would feel travelling in an autonomous car or having goods delivered autonomously. The results showed that people were more comfortable having goods delivered in an autonomous vehicle than if they themselves had to ride in one. The study found that the population is generally positive towards robots (61% are either Fairly or Very Positive). See 2.1. The attitude, however, decreased 3 percent points (pp.) from 2014. EU (2015) showed a -6 pp. decline in the overall positivity towards robots compared to results from 2012. This means that the positive view on robots has gone down -9 pp. from 2012 to 2017 (EU, 2017), (EU, 2015). Another interesting result was, that people were significantly more positive towards robots when they themselves have had experience with one.

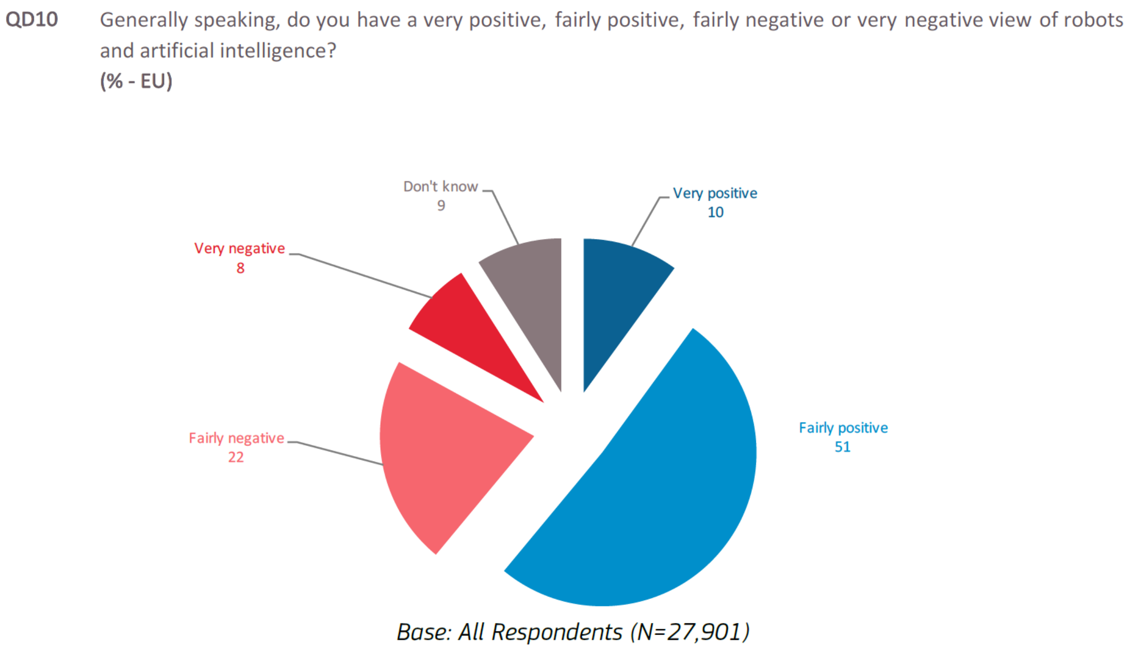


***Figure 2.1.*** Attitudes towards robots and artificial intelligence. Results from EU (2017, p.59)

EU (2017) also presented different robots to the respondents and asked them to what extent the robot corresponded with their personal perception of robots i.e. an industrial robot arm in a factory setting and a more anthropomorphic robot which looked like a service robot in a living room. See 2.2.

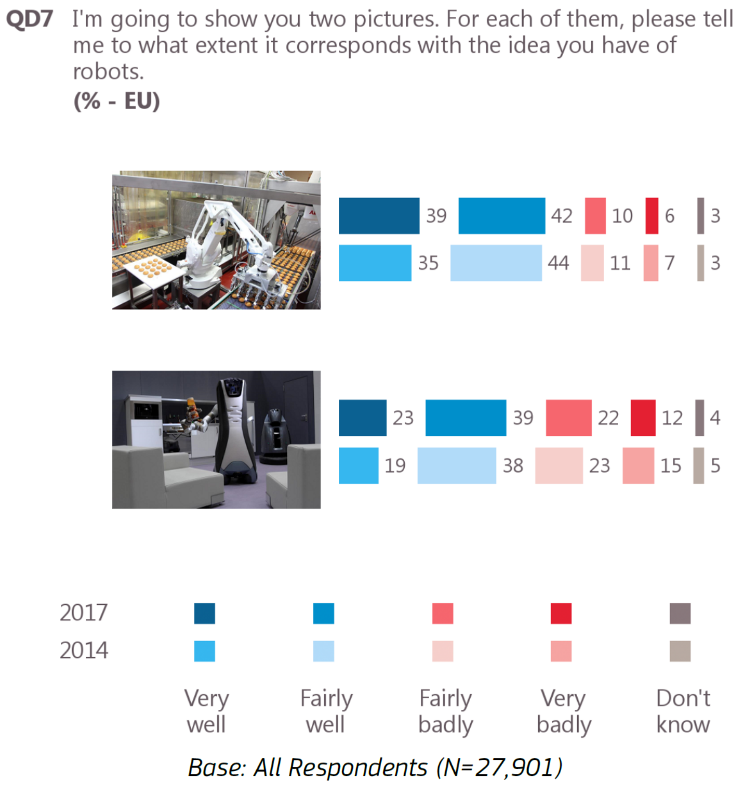


***Figure 2.2.*** The results when asked to what extent an industrial and a more service/social robot corresponds to their idea of a robot. It showed that people were much more likely to say the industrial robot corresponded to their idea of a robot. From EU (2017, p.46)

The results from EU (2017) shows that the people in the EU are still much more likely to see an industrial robot as corresponding with their idea of a robot. The results more or less reflect the 2014 study in which they were shown the same images. This time, however, the proportion of people who thought the service robot corresponded "Very well" or "Fairly well" with their idea of a robot increased 9 pp. compared to 2014, where the industrial robot increased only 2 pp. This could mean that the general view of robots is slowly shifting to also include the more anthropomorphised units.

The report also touches on the risk of losing jobs to robots and other socioeconomic related consequences like income and education and their effects on the positivity towards robots. A majority of people tend to agree that AI and robots are beneficial for society. People, however, seem more negative when asked about robots' impact on the job market compared to the results from 2014 and the study shows that more than seven out of ten tend to agree that robots and AI steal more jobs than they would be able to create. Speculating on this paradox, that people largely view robots as beneficial, but also fear them more, might be related to the uncertainty of how it might effect society. It is not possible to predict how the effect of robots might be in the future which could make some people fear it. On the other hand, there are some benefits right away when implementing the robots, as they can be used to make some improvements which could cause the people to be positive towards robots, as they can see how it might help right now.

In regards to socio-demographics, fairly consistent results were reported thoughout the study. Men, younger respondents, those with higher educational levels, those who use internet daily and those with less financial stressors are generally most likely to be positive towards robots, and the use of them at work and in other contexts in life, (EU, 2017). People who have read or heard about AI in the last 12 months are more likely to have a positive view towards robots. This could mean that the more informed of the subject a person is, the more positive they are. It could also just be an indication, that people who are interested in reading about AI, naturally are more positive towards robots and AI.

More than eight out of ten have never interacted with a robot at home or in the workplace, yet more than six out of ten remain positive towards robots and AI. There seems, however, to be far less comfort with the application of AI and robots in certain situations. E.g. only one in four would be comfortable with a robot performing a medical procedure, driving in an autonomous car in traffic or providing companionship to the elderly, (EU, 2017).

The report concludes that people generally agree that the impact of these new digital technologies on the economy, society and overall quality of life, is positive. Despite the general positive view towards robots and AI, there exists a common belief that these AI and robot technologies require careful management - close to nine out of ten people agree with this statement. Interestingly, people who have read or heard about AI in the past 12 months are more likely to answer that it requires careful management.

These EU studies shows the importance of conducting HRI studies and exploring people's experiences with robots and collect data prior to interacting with them. The EU studies informed our thinking in this project and was taken into account when deciding what relevant questions to ask the participants in the studies conducted later in this report.

## 2.2 HRI in the wild at a Science Museum

According to Jung and Hinds (2018) there is still a need for conducting more studies that focus on exploring HRI in complex social settings similar to where robots nowadays are beginning to be placed and will be placed more frequently in the future. This was also emphasised in the article by Rahwan et al. (2019) which was a work written by leading researchers in multidisciplinary fields. The advantage of conducting studies in complex social settings versus in the laboratory is to get an understanding beyond one single person interacting directly with the robot and also explore the influence of surrounding factors and multi-person contexts. Taking the robot out of the lab and observing the HRI in the wild is by Sabanovic, Michalowski, and Simmons (2006) described to be important when designing robots that are to be socially responsible and responsive. By conducting an in the wild study, Sabanovic, Michalowski, and Simmons (2006) were able to make design suggestions, where the robot was able to take advantage of the affordances found in the environment and also understand the different patterns of surrounding motion. These suggestions are unlikely to be made from a study conducted in the lab and stresses the importance of the setting when conducting HRI experiments.

Silvera-Tawil, Velonaki, and Rye (2015) and Herath, Jochum, and Vlachos (2018) are both examples of HRI studies conducted in the wild where both conducted research at a museum. Silvera-Tawil, Velonaki, and Rye (2015) concludes that the context for which the experiments are conducted is important and that they believe that participant bias is reduced at an in the wild experiment compared to an experiment conducted in a laboratory setting. It seems that the conclusions in Silvera-Tawil, Velonaki, and Rye (2015) have yet to be validated as the experiments in their study were only conducted in one of the settings, in the wild, and not in the laboratory setting as well. Furthermore, Silvera-Tawil, Velonaki, and Rye (2015) found that the participants at the museum had a more exploratory attitude towards the robot than they might have had in other in-the-wild settings, as these different settings might have different social norms which leads to different biases. E.g. people at a museum are perhaps more likely to be in a contemplative mindset than people at a grocery store. To investigate these conclusions, an experiment with the context and setting as variables should be conducted and the findings in each setting compared.

Several advantages to conducting HRI research in the wild at a museum has been described but there are also challenges to be aware of when conducting research in this setting. Some of these challenges described by Herath, Jochum, and Vlachos (2018) are the lack of capability to control an equal number of participants for each of the conditions in the study, as the participation was voluntary and limited to be within the opening hours of the museum. Another challenge was the ethics requirements which limited the participants to only include participants over 16 years old. These challenges, along with the participants knowing that they were being observed, are important to be aware of as they might effect the behaviour of the participants and their interaction with the robot.

Based on their study, Herath, Jochum, and Vlachos (2018) suggests that the discrepancy found between self-reporting and real-time interactions is compounded by the bystanders which are findings that very much relates to exploring the influence of surrounding factors and multi-person contexts, which Jung and Hinds (2018) described as unique for in-the-wild studies and once again stresses the context as an important factor for the findings of a HRI study.

## 2.3 Tools for measuring HRI

When exploring the interaction between humans and robots, and how humans perceive robots, it can be valuable to measure the perception of the HRI.

Aly, Griffiths, and Stramandinoli (2017) stresses the difficulties in defining clear metrics and benchmarks for the different aspects of HRI, which could be helpful when wishing to compare different systems and avoid application-biased evaluation when doing so. Several studies have tried to measure the HRI, but the Godspeed questionnaire developed by Bartneck et al. (2009) have been used several times. It consists of five short 5-point likert scale questionnaires where Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety of the Robot are measured. The Godspeed questionnaire is described by Sim and Loo (2015) as a thorough method to get a good overall evaluation score of the HRI and can be used in many different kinds of HRI research. It is recommended by Sim and Loo (2015) to combine the use of the Godspeed questionnaires with psycho-physiological measurements to introduce a more objective measurement, as they find the Godspeed questionnaire to be more subjective and thereby possibly biased.

Broadbent (2017) states that it is important to focus on and learn from fields within psychology when exploring HRI. Methods already used in psychology might be relevant to apply in the field of HRI. Broadbent (2017) finds that the field of HRI is still a relatively new field of research i.e. it is in an exploratory phase. Broadbent (2017) belives that the ways humans respond to robots and how humans work with robots needs further research.

Sim and Loo (2015) looked extensively at all the major HRI assessment and evaluation methodologies mainly from the year 2000 till 2014, and constructed 4 summarised tables on the Primary and Non-Primary Evaluation Methodologies. Their work provides a great overview of the methodologies used in HRI and are focused on social assistive robots.
Building on this, a paper by Lindblom and Wang (2018) several perspectives on human-centered evaluation in Human-Robot Collaboration (HRC) are addressed. They present an evaluation framework on HRC that focuses on safety, trust, and the interlocutor's experience when interacting with different robots. The framework could be used as inspiration for this project. Lindblom and Wang (2018) claims that the framework is still a work in progress and needs further validation, which is important to be aware of when looking at the framework.

So far the focus in this literature review has primarily been on the interaction, but there are several factors beyond the actual interaction that is relevant to investigate when trying to analyse and measure the HRI. Vlachos, Jochum, and Demers (2016) states that is important to understand how people perceive a social robot both prior and after the actual interaction with it. Furthermore Andrés et al. (2015) found it important to understand the setting where the interaction is happening and the features of the robot in the interaction. De Graaf and Allouch (2013) found that both utilitarian and hedonic factors should be researched when looking at the acceptance of social robots. They found that the important utilitarian factors are usefulness and adaptability while the important hedonic factors are enjoyment, sociability and companionship.

## 2.4 The state of the art in Social Robotics

In this section it will be outlined what aspects should be considered when designing a social robot. Two recent commercial social robots will be mentioned and the rest of the section is meant to introduce different paradigms used within social robotics and will mainly focus on a recent article by Lazzeri et al. (2018), which describes the development of a new social robot platform called FACE (Facial Automation for Conveying Emotion), which is an example of where the technology of cognitive social robotics is today within research.

The first artificially intelligent robot was developed over the span of six years from 1966 to 1972, (Kuipers et al., 2017). Fittingly, it was dubbed "Shakey" after the way it shook when it moved around. It was able to analyse its environment and objects in it, it could plan accordingly to achieve a goal state, and it could physically carry out that plan in a dynamic world. The technology developed for Shakey is still used in today's AI systems e.g. image segmentation in computer vision systems. As some of the researchers who worked to develop Shakey, Peter Hart and Nils J. Nilsson, puts it: "We researchers in artificial intelligence during this time in history have the privilege of working on some of the most fundamental and exciting scientific and engineering problems of all time: *What is mind? How can a physical object have a mind?* (Kuipers et al., 2017).

These questions are still very relevant today, as we still do not have a clear answer to those, despite giant advances within AI and robotics. Today we have robots that look very life like, such as Hiroshi Ishiguro's Geminoids which are made to replicate existing people as close as possible, (Ishiguro and Libera, 2018, ch. 1,2). Another famous humanoid is called Sophia developed by Hanson Robotics. The robot made headlines in 2017 when Saudi Arabia granted Sophia with an honorary citizenship, (IEEE, 2019). Providing a robot with a citizenship sparked a big debate over human rights in general and specifically in regards to AI, which, according to Hanson Robotics' website, is exactly what Sophia was created for - to help educate the world and raise questions about humans' role in society along with discussions about AI ethics, (HansonRobotics, 2019).

Humanoid robots are not examples of consumer products that an average person can venture out to buy and perhaps do not reflect the current state and ability of social robotics. On the contrary, such examples include the Jibo robot (Jibo, 2017) and the Vector, made by Anki (Anki, 2018) pictured in Figure 2.3. Jibo can be seen as an embodied version of Amazon Echo or Google Home. They act as smart companions for your home but with a personality and the ability to recognise individuals whom they have seen. The Vector robot can be coupled to Amazon Alexa and is a small, mobile, autonomous desktop helper which uses deep neural networks to explore its surroundings. Common for both robots is that they use a great deal of smooth expressive movement when interacting with their environment. The Vector robot has by some been compared to Disney's animated robot character "Wall-E" and the animated eyes does a lot to express emotion. Both robots rely on cloud connectivity, and they are both meant to companions unlike Amazon Echo or Google Home, which is more commonly perceived as a tool. Unfortunately, both companies recently announced that they have closed its doors and soon the servers, which their cloud connectivity and speech recognition rely on, will most likely be taken down as well. According to anecdotal evidence presented by Fisher (2019), even if the company failed, the reaction from many costumers implied that the robots succeeded in creating a strong sense of companionship and thus evoking strong emotions of loss when people learned that their robots' ability to speak might soon disappear with the servers.

***Figure 2.3.*** Examples of consumer social robots. To the left, Jibo. It has facial recognition and natural language processing. To the right is the Vector robot which is mobile and designed to be a little desktop helper. Jibo picture from `https://aiscores.com/jibo/`, Vector picure from `https://www.anki.com/en-us/vector/vector-aware.html` - Accessed 2019-05-02.

Lets return to the questions *What is mind?* and *How can a physical object have a mind?*. A recent publication by Lazzeri et al., 2018 asks the same questions and have tried to build the mind of a social robot using state of the art technologies and combining interdisciplinary knowledge from multiple fields such as behavioural and social psychology, neuroscience, affective computing, computer science, and AI. Social psychology helps to define how people react to different stimuli, and essentially helps to develop the behaviour of the robot. Computer science creates the software which control this behaviour and interactions with the environment. Affective computing is essentially a field which focuses on the robot's ability to interpret the emotional state of the interlocutor and enables the robot to adapt its behaviour and convey its emotional state accordingly, (Picard, 2000, ch. 2). Because the mind is so complex it has to draw on multiple disciplines which has led to a rather novel paradigm called Cognitive robotics in which researchers now try to mimic the human cognition. Some are of the belief that, in order to successfully create an intelligent social robot, one has to develop a biomimetic system, that represents a faithful reproduction of the human brain structure, (Pfeifer, Lungarella, and Iida, 2007). To the best of our knowledge, such a complete system does not exist. But as technology and the knowledge of the human brain structure advances, it might not be science fiction for long.

Lazzeri et al. (2018) describes a new research paradigm called embodied artificial intelligence which draws on the extensive work on cognitive paradigms within AI and robotics done by Vernon, Metta, and Sandini (2007). Vernon, Metta, and Sandini (2007) dives into the different paradigms within cognitive robotics and makes a distinction between a *Cognitivist* approach and an *Emergent systems* approach. The cognitivist approach is of the belief that cognitive systems should be built on symbolic information processing representational systems. It leans on the more classical view that cognition is a type of computation. Whereas the emergent systems approach is embracing connectionist systems, dynamical systems, and enactive systems distances themselves from the symbolic, rational, structured and algorithmic approach of cognitivist systems, and instead believe that cognition should be treated as an emergent, dynamical, and self-organising interconnected system, (Vernon, Metta, and Sandini, 2007). Since 2007 it appears that the emergent systems approach has shown most promise, and is also what Lazzeri et al. (2018) built their FACE (Facial Automation for Conveying Emotions) robot on. Embodied artificial intelligence seeks to build autonomous agents that would be able to adapt dynamically to its environment and also manipulate said environment physically with its body. Essentially the agent should be capable of building a world model and be able to create abstract representations of the world model in order to discover what is feasible in various situations.

According to Lazzeri et al. (2018), these capabilities mean having a mind and conclude that it would require both a body and a mind in order to successfully build an intelligent embodied agent. Like humans, the agent should be able to observe the world around it and acquire knowledge via its body, and then use the mind to be able to sort this information into applicable knowledge and behaviour control. Also, the agent should have a social intelligence in order for it to successfully engage in meaningful social interactions with humans. Lazzeri et al. (2018) lists eight elements, they believe, are needed to build a cognitive system for an intelligent agent in order to create a mind:

1. A distributed modular architecture that allows for the design of a system with multiple abstract and physical layers, with parallel processing and distributed computational loads.
2. An imperative control architecture aimed at controlling low-level procedures such as motor control, sensor reading, kinematics calculation, and signal processing.
3. A hardware platform robot-independent low-level control architecture that can be easily adapted to various robotics platforms and consequently used in various research, commercial and therapeutic setups.
4. A deliberative reasoning high-level architecture aimed at implementing the robot's behavioural and emotional models.
5. A pattern-matching engine able to conduct search and analysis procedures that are not necessarily describable with boolean comparisons or mathematical analyses
6. An intuitive and easy-to-use behaviour definition language that allows neuroscientists and behavioural psychologists to easily convert their theoretical models into executable scripts in the cognitive architecture.
7. A high-level perception system aimed at extracting high-level social, emotional, and empathic parameters from the perceived scene, with particular focus on the interpretation of humans' emotional and behavioural signs.
8. An object-oriented meta-data communication and storage system on which data of heterogeneous categories can be easily managed and elaborated.

These eight requirements boils down to a system which is not built around a single monolithic control architecture, but, like the human brain, is capable of parallel processing. It should have social intelligence, which covers the understanding of other people's emotional state and be able to quickly adapt and behave appropriately to its current surroundings. Item 3 and 6 tries to ensure that the system is applicable to not only one specific platform, but could be applied on various platforms. Especially 6 seems important if a robot should ever succeed in long term social interaction.

### Brief overview of cognitive paradigms

According to Lazzeri et al. (2018), there exists three main paradigms built around three primitives SENSE, PLAN, and ACT. They are called: *Hierarchical*, *Reactive*, and *Hybrid* *deliberate/reactive paradigm*. See Figure 2.4. The first AI robot, Shakey, operated with a hierarchical paradigm. See **(a.)** on Figure 2.4. As mentioned earlier, it was able to analyse its environment and objects in it, plan accordingly to achieve a goal state, and would physically carry out that plan. It would operate in a hierarchical feedback loop. However, if one prior step failed, the whole system would fail. This is further illustrated by the different pillars on the right in Figure 2.4 - it has to pass through each one of them stepwise. It is not very flexible in that regard.

The reactive paradigm, pictured as **(b.)**, does not have a PLAN element, but is much more direct in its behaviour as it has action modules acting in parallel with each other. This paradigm was pioneered by Rodney Brooks in 1986 where he called it a Robust Layered Control System, (Brooks, 1986). As illustrated in Figure 2.4, it does not have to go linearly through its cognitive process, but it is able to act from input in each module in parallel. This would be characterised by Vernon, Metta, and Sandini (2007) as an emergent and dynamical system. The lack of a planning system, however, means that it is incapable of defining the best approach to solve a specific problem.

The last paradigm, illustrated by **(c.)** on Figure 2.4 is the hybrid deliberative/reactive paradigm. It is what the FACE robot was designed with. It can be described as PLAN, then SENSE-ACT but the three primitives are not clearly separated which creates a very dynamic paradigm. This would mean that it could have a clear objective, having planned the best way to achieve it, while still allowing the attention to be grabbed by other stimuli. E.g. the agent would react to a loud noise, turn its head to investigate,

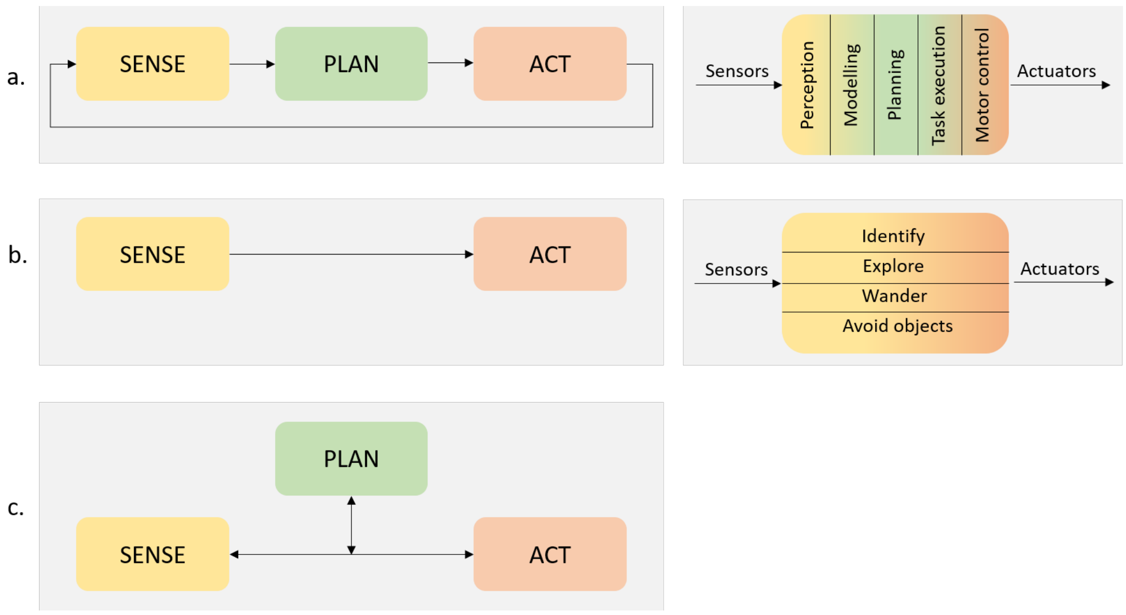


***Figure 2.4.*** A rough depiction of three different paradigms. **(a.)** depicts a hierarchical paradigm. The system is linear, senses its environment to create a model, makes a plan to achieve a specific goal, and carries out the first step of the plan. **(b.)** Is called a reactive paradigm and is emergent/dynamic, can exploit parallel sensory input **(c.)** is a hybrid deliberate/reactive paradigm, which has kept the PLAN module, but communicates dynamically. This figure resembles figures shown in Lazzeri et al. (2018).

and afterwards return to the primary objective which it would still have been able to process while attending the noise. It is usually built around a low-level reactive control and a high-level deliberate control which controls this deliberative and reactive behaviour, (Lazzeri et al., 2018). See Appendix B for a more detailed description of FACE's cognitive architecture.

### Capabilities of the FACE robot

The FACE robot is able to keep track of individual humans in a room including their posture in order to analyse their body language. It is also capable of differentiating between male and female. Even for a humanoid robot, the FACE robot has received a very realistic human face as is shown on the left on Figure 2.5. The face itself has been fabricated by Hanson Robotics (`https://www.hansonrobotics.com/`) - the same company which developed the humanoid, Sophia, we mentioned earlier. Using 32 different motors, the FACE robot is able to produce a wide range of different emotional expressions, such as disgust, surprise, happiness etc (Lazzeri et al., 2018).

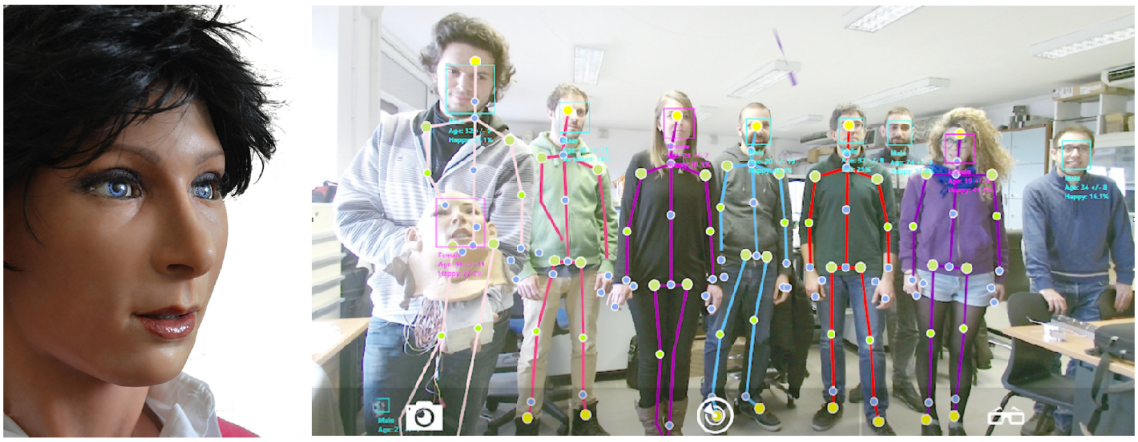

***Figure 2.5.*** The FACE robot is seen to the left. The right side depicts its ability to analyse individual humans in the near vicinity including their body posture and gender. The blue squares indicates males and the pink, females. The images are found in Lazzeri et al. (2018).

What we have presented here was one case of a technologically advanced social robotics system called FACE (Facial Automaton for Conveying Emotions). It takes a lot of effort and multidisciplinay skill in order to design, what appears to be, a socially intelligent autonomous agent. This was an example of where an area within social robotics is today. Lazzeri et al. (2018) concludes that body and mind goes together when building an intelligent embodied agent, seen from a biological and robotic perspective. How well this system will fair is not clear, although, the authors have conducted research using the platform to show its benefits within therapy of autistic children to emulate real-life social interactions. Also, they claim to have an article under review in which their FACE robot's facial expressions were comparable to those of a human. The system has not yet been tested outside of a laboratory.

Besides the possibility of a cognitive architecture in a robot, what other important considerations do one need to factor in when designing a social robot?

### Important factors when assigning agency or animacy

If we take a step back from complex cognitive structures, a lot more simple setups have revealed a great deal on how humans assign animacy and agency to an object - more specifically a robot (Castro-González, Admoni, and Scassellati, 2016), (Kroos, Herath, and Stelarc, 2012). In this context, animacy means the quality to be perceived as a living entity, rather than an inert object. Agency means to perceive an object as having intent. A very famous study by Heider and Simmel (1944) demonstrated quite clearly, that objects do not even have to appear anthropomorphic (or zoomorphic for that matter) in order for humans to assign animacy and agency. They did so by creating an animation using only geometric shapes like triangles, a square, and a circle. Shear movement of the geometric shapes was able to convey a story where all participants except one described the shapes as if they were living actors involved in a chase.

Castro-González, Admoni, and Scassellati (2016) investigated the relationship between movement and humanoid appearance though a game of tic tac toe. They found that dynamic movement significantly contributed to peoples' perceived animacy towards the robot. They found that movement characteristics in general influenced people's sense of likability, animacy, and unpleasantness.

This fits well in line with how humans process information in social interactions. Here, the body language of the interlocutor has primacy over verbal communication (Grebelsky-Lichtman, 2017), (Grahe and Bernieri, 1999). E.g. you are able to know straight away, if your friend is not all right, despite verbally informing that they are, based on their body language, or you might be able to tell if a person is genuine by the way they smile (not smiling with the eyes could indicate that they are not etc.). Hale and Stiff (1990) also showed that people rely heavily on non-verbal cues when judging veracity. This in turn means that humans are highly sensitive to non-verbal communication in social interactions.

This is important to keep in mind when designing future social robots. They likely require naturalistic movement in order for humans to trust the information they convey. This non-verbal primacy also shows when people communicate through text based services such as online messaging. In certain situations it can be difficult to convey the right intention or emotion through text alone when the non-verbal cues are missing, (Walther, Loh, and Granka, 2005). The use of emojis might help facilitate this emotional communication if used correctly. Still, cues like body lean, posture, eye contact etc. are missing.

Studies have also found that people attribute a greater sense of mental state and intentionality if a robot cheats when interacting with it through a game, (Short et al., 2010). Short et al. (2010) utilised a Baxter robot in a game of tic-tac-toe against a human. The timing, however, of what is essentially an error, is crucial in the way that it is perceived by the participant. If the robot just made an illegal move, it was perceived as an error. If the robot instead changed its answer, it was perceived as intentionally cheating which is what contributed to the greater sense of mental state. It is rather ironic that a trait we as humans normally deem immoral and unfair contributes to a robot being perceived as more human-like.

## 2.5 The Articulated Head

The robot that we will focus most of our attention on has been dubbed The Articulated Head (AH). It has been a popular art installation at the Powerhouse Museum in Sydney for two years and is currently being updated and will be installed at a science museum. The AH has served as a great platform for combining HRI research and art in the past and now continues to do so (Kroos, Herath, and Stelarc, 2012). The AH sprung out of an art work called The Prosthetic Head from 2003 by Stelarc, an Austalian performance artist (Stelarc, 2003). The Prosthetic Head was presented at an international festival of live arts in Glasgow in 2003. Here the art installation consisted of an animated 3D model of Stelarc's head projected on a wall. The head used animations to mimic oral and overall facial expressions. The installation was coupled with speech software and equipped with motion sensors and simple computer vision which was able to detect the colour of a person's clothing and include it in the conversation in an attempt to make the experience more interactive. As Kroos, Herath, and Stelarc (2012) puts it, The Prosthetic head was not meant to be "an illustration of a disembodied intelligence. Rather it raises questions of awareness, identity, agency and embodiment."

Later, the head was updated in a research project called "From Talking Heads to Thinking Heads: A research Platform for Human Communication Science" spanning from 2006-2011. The work is partly described in a report from 2008, (Burnham et al., 2008). In this report, the authors set up an experiment in order to test people's comprehension of two different texts recited by the talking head. They wanted to investigate to what extent facial expressions on the virtual agent affected this comprehension. They also looked into how engagement and head-expressions might affect comprehension. They found that if a text is recited in a humorous manner, it appears that comprehension deteriorates. Burnham et al. (2008) discovered that immediate emotional expression might not be the most effective way to communicate as it could take attention away from comprehension. In relation to the work presented in Lazzeri et al. (2018), this is a very important finding to note. Their FACE robot is capable of expressing immediate facial expressions, but that could possibly negatively affect the interaction.

Over the span of the research project presented in Burnham et al. (2008), the Prosthetic Head was also displayed in a New Media Arts Exhibition at the National Art Museum of China in Beijing where it was projected 4 metres tall on a wall. It also appeared in a more exotic form dubbed The Walking Head, which was an embodied robot installation with 6 legs and an LCD monitor mounted with the head. It was 2 metres in diameter and confined on a 4 m diameter pedestal. It was autonomous and would detect when people were close, stand up, do a pre-programmed choreography and sit down until it detected a new person (Stelarc, 2006). The latter was first exhibited at Heide Museum of Modern Art in 2006.

The Articulated Head (AH) can be seen as an embodied version of the virtual Thinking Head. Combining both the art from the Prosthetic Head with the engineering achievements attained from the Thinking Head Project. The concept is an interactive agent for the visitors to converse with, like an Embodied Conversational Agent (ECA). Previously, the platform was utilising a Fanuc LR Mate 200iC robot arm with an LCD display mounted. Here, too, they used the virtual 3D facial scan of Stelarc, which was able to produce various expressions depending on the interaction. A new attention system was developed for the head, called the Thinking Head Attention Model and Behavioural System (THAMBS) which tries to mimic how the human brain processes information by having distinct centres for each sensory modality in order to process the incoming information and afterwards act responsively. This structure is very reminiscent of Rodney Brooks' Reactive paradigm previously illustrated in Figure 2.4. This was a much more comprehensive system than what was previously deployed in earlier versions. Visitors who engaged with the robot were able to converse with the Articulated Head via a screen and a keyboard. The Articulated Head was then able to reply back using a synthesised voice coupled with an intelligent language algorithm. An overview of how the THAMBS works is shown on Figure 2.6. With the ability to process sensory input from cameras and microphones, the AH could adapt dynamically to the specific situation it was in - it responded to its environment. AH had different thresholds built in order to control where to direct its attention. E.g. if a loud noise went off, it would turn to the direction of the sound source (Kroos, Damith, and Stelarc, 2011). Some interesting results concerning perceived agency are mentioned in the article including some unexpected incidences with children seemingly playing hide and seek with the robot. A completely novel way of interacting with the AH, seen from the researchers' perspective. The children discovered that the AH could not see them when they were crouching down. The tracking system could not detect people below 0.5 m. When the children carefully stood up, the robot turned its head towards them while adjusting its height to look down on them. When discovered, the children would hide in a new location, out of reach of the tracking system (Kroos, Herath, and Stelarc, 2012). A game quite similar as one might play with a dog. Breazeal (2003) makes a great argument that the social structure of a dog is quite different compared to a human's, one might even say beneath a human's, yet, it is a very genuine interaction and relationship that exists between man and dog. This goes to show that successful social interaction should not be confused with developing a robot that is indistinguishable from a human being inside and out. It matters how the face-to-face interaction is experienced, (Breazeal, 2003). This novel hide and seek with the Articulated Head also shows how responsive movements in robots play a key role in evoking agency. So much so, perhaps, that a big complicated cognitive control architecture built around conveying and understanding emotions simply is not necessary as these findings in Kroos, Herath, and Stelarc (2012) show how a great user experience is created from responsive movement. It could suggest that much of the interaction also lies with the person interacting with the robot in a way where they fill in the blanks, and project more capability on to the robot than what is objectively there.

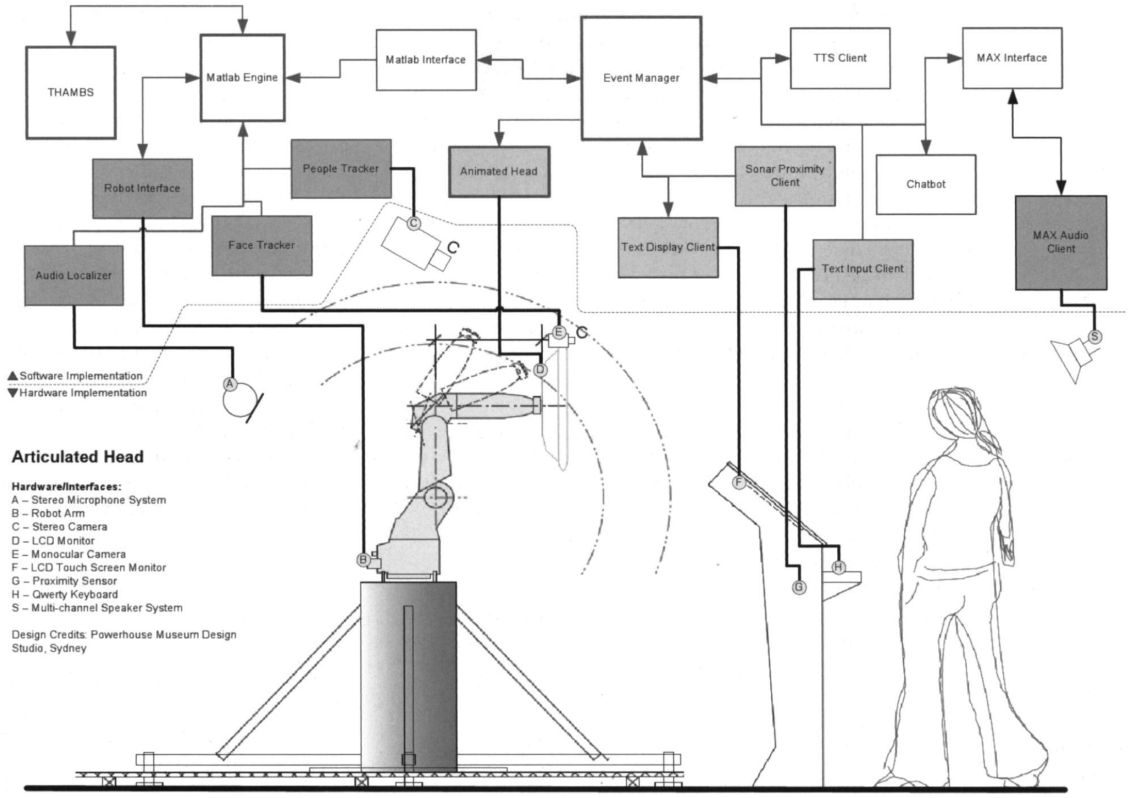


***Figure 2.6.*** A condensed schematic showing the different modules of the THAMBS including the hardware and setting involved. ©Damith C. Herath. Design: Powerhouse Museum Design Studio, Sydney (Kroos, Herath, and Stelarc, 2012)

The Articulated Head is now set to be updated with a new robot arm and will appear in a new setting and exhibition at Questacon. The choice to move on to a new arm comes in wake of the paradigm shift towards collaborative robots, described in Chapter 1, and how the robots are increasingly getting closer to interact with humans on a daily basis without the previously necessary barriers. The old robot arm was a classic, very powerful industrial arm, hence the need for physical barriers. The new arm is utilising the UR10, a collaborative industrial arm safe to work side by side with humans with no barriers. It will be important to further HRI research to explore these interactions with no barriers as all points to that being the direction we are headed. With the transition onto the new arm comes also a new 3D scan of Stelarc's head to be implemented. This creates a lot of new challenges for the development of the Articulated Head 2.0 (AH 2.0). The UR10 robot arm is engineered and behaves differently compared with the old Fanuc arm. The visual graphics are now rendered in much greater detail but the facial animations that were tweaked over the span of multiple research projects (Burnham et al., 2008) need to be transferred to the new virtual build in order to retain the convincing interactions that were found in Kroos, Herath, and Stelarc (2012) and improve on them. See Figure 2.7 for a comparison between the old head and the new head.

Among raising these transition challenges and questions such as agency and embodiment, other questions arise too regarding the ethics and responsibility surrounding the robot. On Stelarc's own website about the Prosthetic Head (`http://stelarc.org/?catID=20241`) it says: "A problem would arise (...) when the PROSTHETIC HEAD

***Figure 2.7.*** A comparison of the original Articulated Head animation (left) and the new animation set for the Articulated Head 2.0 (right). Left picture is from Stelarc (2003). The right picture is used with permission from Questacon.

increases its database, becoming more autonomous in its responses. The artist would then no longer be able to take full responsibility for what his head says." Is this right? Who then should be held accountable for the opinions and possible actions of artificially intelligent agents?

# Problem Analysis 3

The topics in the literature review created the ground work for an analysis of the problem that this project will aim to address and provide further understanding of.

**Perception of Robots**

we found it important to also explore factors outside of the actual interaction when trying to understand what factors influence the interaction with a social robot. Factors that are not part of the actual interaction, but are still relevant to explore, are for example the human's perception and understanding of robots prior to the participant's interaction with the specific robot being studied.
It could both be important to understand how the participant's previous experiences affect the interaction being explored or it could be how the explored interaction might affect the participant's general perception of robots. These are factors related to the human, but there are also important factors related to the robot. When exploring the perception of a robot an important factor is how the robot moves and how it is programmed to behave. Kroos, Herath, and Stelarc (2012) purposed that agency of the robot is evoked and not instilled. Meaning that the interplay between how the robot behaves and its environment evokes this agency. It is as much the actions of the robot as it is the robot that creates the perceived agency of the robot.

Based off our literature review, we found it relevant to explore the agency and the perceived animacy of the robot because it seems that it is very beneficial in creating meaningful interactions with the robot. If a robot is merely seen as a mechanistic kinematic sculpture, there would probably not be any notable engagement. It seems it gets easier for a participant to relate to a robot if the robot has perceived animacy. As Heider and Simmel (1944) showed many years ago, simple shapes can be perceived as animate and as having intent. We believe that this translates to physical objects such as robots as well, where the interlocutor fills in the blanks and assign agency to, what is essentially, an inanimate object set in motion. Breazeal (2003) also notes that an anthropomorphic appearance not necessarily creates a great interaction, though, it matters how the face-to-face interaction is perceived.

**Setting of HRI**

The initial problem formulation addresses how to get an understanding of how the setting might affect the human robot interaction. In the literature review more studies were found to have been conducted in the laboratory setting compared to studies conducted in the wild.

Both the setting and the context of the human robot interaction is relevant to further investigate in order to understand how these might affect the interaction and to what extent results from a study in the laboratory transfer reliably to real world settings. It is important to make a distinction between context and setting as these are not the same and might affect the interaction in different ways. The setting for the HRI is the physical space where the interaction is taking place. To investigate how different settings influences the interaction with a specific robot, a study with the same robot should be conducted in different physical spaces.

The context of the HRI is the situation where the interaction occurs. Unlike setting, investigating the context does not require that the physical location change, it might be enough to create a simulation or suggest the context, without altering the setting. This is previously done by Herath, Chapman, et al. (2011) that found that the perception of wearing a wearable robotic device was affected by the context.

This project focuses on the setting and context of a science museum because the robot the Articulated Head will be exhibited in such a space. It gives the opportunity to test the robot in this setting and context and compare to other settings. For this project it is chosen to only focus on the possible effect of the setting of the HRI. This choice is based on the plan for the robot to actually be moved from one setting to another, which gives a natural occurring change in setting for the robot.

The context of the robot will not be varied in this study, partially because it is found necessary to limit the scope of the project but also because the Articulated Head, at this stage, only is planned to be in the context of a Science Museum. Instead of varying the context it will be explored what context the participants might see the AH in based on their interaction and experience of the robot.

**Data collection**

Based on the literature presented in section 2.3 it was found that using a mixed method approach could be an advantage and provide valuable findings. This raises the question of how to collect both objective and subjective data about the robot and the interaction with it and at the same time combining self-reported data with observational data to understand the interaction.

Reflecting upon the best way to get an understanding of the interaction with the robot will be done by using the experience of previous research conducted in the field of Human Robot Interaction. Methods used in previous studies will be used and adjusted to the studies conducted in this project. Through the literature review on tools used for measuring HRI it was found that the five Godspeed Questionnaires by Bartneck et al. (2009) would be a good tool for measuring the HRI.

## 3.1 Problem Formulation and Research Questions

Based on the literature review and problem analysis, a problem formulation was created and finalised during the project. The final problem formulation is as follows:

> *What are the essential aspects for developing a convincing and engaging interaction with a social robot in a science museum? To what extent do the results from a study in the laboratory transfer reliably to real world settings?*

The problem formulation addresses the overall research goal of the project, but to address this problem formulation, we found necessary to formulate more specific research questions with the purpose of addressing these research questions in different settings to provide research findings to address the overall problem formulation. The research questions that are addressed in the studies are:

1. *How do participants interact with the AH in the context of a Science Museum?*
2. *How do participants experience interacting with the AH?*
3. *What is the perceived animacy of the AH? And how might it be related to the movement of the robot?*
4. *How can a mixed-method approach be implemented in an HRI study conducted in different settings?*
5. *How might we explore possible contexts in which the AH could be implemented in?*
6. *How can the group dynamic found between visitors at a science museum be implemented in the study?*

The problem formulation and research questions was addressed in this project in an iterative exploratory process.

These research questions will be used throughout the project to guide us in the process and help us better answer the questions asked.

# Grounding Study in the Wild at Questacon 4

The empirical data first planned and last collected in this project was from a grounding study conducted at Questacon - the National Science and Technology Centre. The purpose of this Grounding Study in the wild was to explore the general expectations and experiences of and with robots. This was done by conducting a study at the exhibition *Born or Built?* about robots, AI and human societies. To get an understanding of the exhibition prior to conducting our grounding study there, we conducted two interviews: one with the curatorial team and one with Dr. Damith Herath. The interviews and the knowledge we gained from them is described in Appendix D.

The grounding study at Questacon consisted of two interviews with the visitors and the the walk-along method during their visit at the exhibition to get insights into the visitor experience at the exhibition. The *Born or Built?* will eventually include an exhibit of the Articulated Head, which was the robot we used in all studies conducted in this project. It was valuable to explore and understand the visitor experience at this exhibition because it is a setting where human robot interaction is happening naturally, regardless of us wanting to conduct a study. The visitors come to the museum and pass through this exact exhibition for an experience that includes robots and technology.

Initially the findings of this study should have been used to develop the research design for the main studies addressing our problem formulation, but because this grounding study was conducted after the main studies, the findings of this study is instead used to reflect upon and discuss the findings from the main studies and how the researched design might be adjusted before conducting a study at Questacon. To be able to answer our problem formulation about the essential aspects for developing a convincing and engaging interaction with a social robot in a science museum, it was important to understand the science museum as a setting and that was what this grounding study provided.

## 4.1 Study design

The study has three elements: one is a semi-structured interview at the entrance of the exhibition, second is walk-alongs during the participants' visit at the exhibition and third is a semi-structured interview at the exit of the exhibition.

The ethical approval for this study can be found in Appendix A.3 and the participation information form and consent form for this study can be found in Appendix A.4.

### Location

The interview at the entrance of the *Born or Built?* exhibition was conducted after the participants had signed consent forms and before they entered the exhibition. On Figure 4.1 the place is showed where the consent form was signed and the first interview was conducted. Questacon had arranged a table to be set up in order for us to brief the participants and have them sign the consent forms.

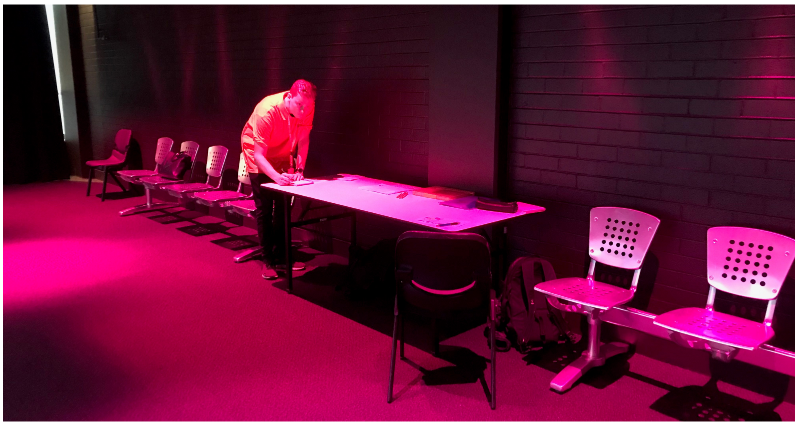

***Figure 4.1.*** The table at the entrance of the *Born or Built?* exhibition at Questacon where the consent forms was signed.

After the first interview was conducted the participants entered the *Born or Built?* exhibition that is shown on Figure 4.2 and Figure 4.3.


***Figure 4.2.*** The ground layout of the *Born or Built?* exhibition. Graphic used with permission from Questacon.


***Figure 4.3.*** The *Born or Built?* exhibition at Questacon. Picture taken from where the participants entered the exhibition.

We accompanied the visitors through the exhibition, where they lead the way. After the participants indicated to the researcher that they were done with their visit at the exhibition, a second interview was conducted. The exit interview was conducted at the table showed on Figure 4.1 or in the exhibition area.

### Questions for semi-structured interviews at the entrance and exit

The questions for the semi-structured interview is partially based on the goal of exploring the expectation to and experience of the exhibition. Some of the questions are based on an interest from Questacon about exploring how the exhibition might effect the visitors opinion on and confidence in discussing technology and what the future might hold for technology. The reason for including questions from Questacon, is to provide them data that is easily collected for us and give them concrete value in having this study conducted at there location.

At the Entrance:

1. Why did you choose to come to Questacon today?
2. Did you hear about the exhibition *Born or Built?* How?
3. What are your expectations to this exhibition?
4. What do you hope to get from attending the exhibition?
5. Is there anything you are especially excited about regarding the exhibition?
6. Have you had any experience with robots before?
7. How optimistic do you feel about our future with technology? (On a scale from 1-10)
8. How confident do you feel engaging in discussions about technology policy/how we use technology? (On a scale from 1-10)

At the Exit:

1. Please describe how you experienced the exhibition as a whole?
2. What was your favourite experience at the exhibition today? Why?
3. What do you feel you gained from attending it?
4. Did you interact with any of the robots today?
5. Is there anything you are wondering about regarding your experiences today?

6. How optimistic do you feel about our future with technology? (On a scale on 1-10)
7. How confident do you feel engaging in discussions about technology policy/how we use technology? (On a scale of 1-10)

### The walk-along method

The method was initially called the go-along method and is described in Kusenbach (2003) and Kusenbach (2018). It is a way of capturing immediate experiences, interpretations and emotions right when they are experienced by the participants. This method can be conducted in different ways, the way we choose to apply this mobile method is to walk along with the visitors while they visit the *Born or Built?* exhibition. The reasoning for walking along is that this is the common way visitors get around at a museum.

The reason we find this method relevant to apply in our grounding study is that it according to Skov, Lykke, and Jantzen (2018) can be used to gain an understanding of the visitors experiences at a science museum and understand the social architecture between visitors, which is relevant to know when studying how groups interact and not only one individual interacting with the robot. The social architecture in a group of participants might affect the interaction and by exploring social architecture between the visitors, it might give further understanding of how several humans interact with a robot.

## 4.2 Findings from the interviews and walk-alongs

The study was conducted over two days, on a Thursday from 9am to 12pm and a Friday from 1pm to 4pm. There was 18 participants, 10 males and 8 females. Two of the participants participated by themselves and the last 16 participants as groups of two.

The data collected in this study was not analysed using any analysis methods due to the late nature of the study. Instead tendencies were found from going through the data and graphically presenting the answers to the two scale questions. The tendencies found and experiences from conducting the study is presented here.

One of the experiences from conducting this study using the walk-along method was that we discovered it provided valuable insight into the visitor's experience. We found a tendency from the conversations with the participants that the method might affect their experience, in a way that made them reflect more about the exhibition, their interaction at the exhibition and what they gained from it. Kusenbach (2003) mentions that when using the go-along method the researcher can influence or even disturb the visitor experience, which our findings might indicate we did to a small extend. Taking the *Born or Built?* exhibition and the goal the exhibition into account, we did not find this method to have a negative influence on the visitor experience. The exhibition inspires discussion and reflection and by using this method increased the likelihood of that happening - some even stating that they really enjoyed having the researcher there because it caused them to reflect more upon the exhibition.

An other tendency found when conducting the study was that the busier the exhibition was, the less immersed the people were. This was found in the time and way the participants interacted with the exhibits. If there was a lot of noise and many people and children, the participants tended to spend less time on each exhibit and not reflect as much, as we found other participants did when it was quieter.

Our last findings were from the two questions we asked before and after the participants visited the *Born or Built?* exhibition. These questions were:

- How optimistic do you feel about our future with technology? (On a scale on 1-10)
- How confident do you feel engaging in discussions about technology policy/how we use technology? (On a scale of 1-10)

The answers to these questions are showed on Figure 4.4 and the data for making these plots can be found in Appendix A.5.

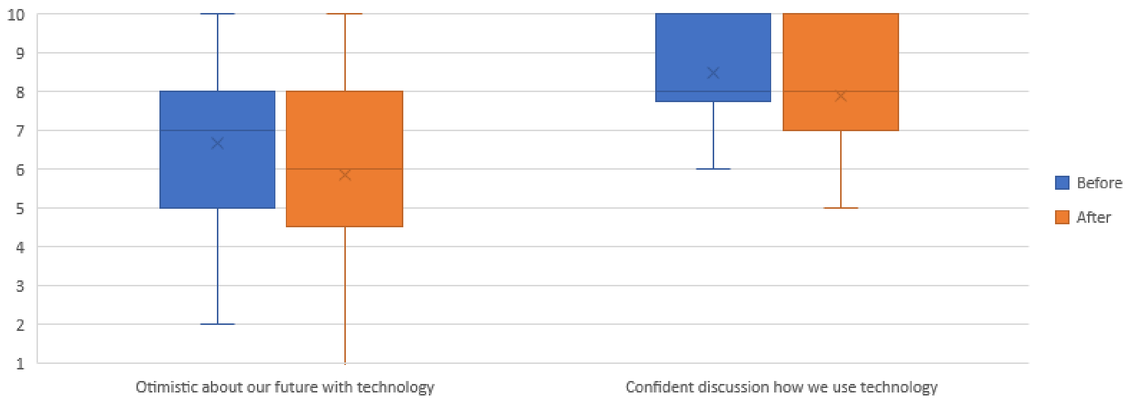


***Figure 4.4.*** Boxplot for answers to two questions asked before and after visiting the *Born or Built?* exhibition at Questacon. The X in the boxplots indicates the mean.

The boxplots of the answers from the participants does not show any big differences between what the participants answered before and after the exhibition. It could look like the answers for both questions is a bit lower after the participants visited the exhibition. It could mean that after the participants had visited the exhibition they felt less optimistic about their future with technology and less confident in discussing how we use technology, than they did before going into the exhibition. This is not unlikely to be true, when also including the researchers' impressions from conducting the walk-alongs and the interviews. Several participants stated that the exhibition made them reflect on how technology might change their future and the importance of being aware of the concerns there might be when implementing more advanced technologies.

The boxplot of their ratings regarding how optimistic the participants were about their future with technology shows that the answers are spread all from 1 up to 10, this indicates a big difference in how optimistic the different participants were. This was an interesting finding compared to the EU study, (EU, 2017).

Our findings indicate that some people were less optimistic about their future with technology after visiting the exhibition. In EU (2017) the results found that people who have read or heard about AI in the past 12 months are more likely to answer that AI and robot technologies requires careful management. The fall in optimism that we found a tendency of in our study could be related to the difficulties and complexity of managing these technologies. The participants might be less optimistic because they get more aware of the difficulties of implementation of these technologies, which would require careful management to make sure the technologies are implemented soundly. It does, however, contradict the other finding from EU (2017) that indicated that the more informed people are on AI, the more positive they are towards it. This again could just mean, that people already positive towards AI reads more frequently about it.

# Grounding Study in Lab with Articulated Head 5

Technology has advanced since the original AH was developed and some of the new technologies will be implemented in the new version of the AH. See section 2.5 for a description of the Articulated Head. One of the changes that has already been made is the robotic arm that the monitor is mounted on. All changes that are to be made from the original AH to the new AH will in many ways change the appearance and movements of the robot.

With this study we address two of our research questions. The first being *2. How do participants experience interacting with the AH?* and the other being *3. What is the perceived animacy of the AH? And how might it be related to the movement of the robot?*. Both questions were addressed by getting the participants to rate the robot on anthropomorphism, animacy, likeability, perceived intelligence and perceived safety, when the robot was moving in two different ways and afterwards by comparing the ratings.

The purpose of this the grounding study was also to get familiarised with the robot that we analysed in our main studies. By conducting this grounding study we also got experience with conducting a HRI study in a lab setting which was a useful experience for improving the research design of our main studies that aimed to address our problem formulation.

## 5.1 Experimental design

The grounding study was conducted in the Collaborative Robotics Lab at UC and aimed to explore how two different positions of the robot influenced the participants perception of the robot. The previous version of the Articulated Head was a LCD monitor mounted on the industrial robot arm named Fanuc LR Mate 200iC (Kroos, Herath, and Stelarc, 2010). The new version of the Articulated Head is a LCD monitor mounted on a different industrial robot arm called UR10, developed be the company called Universal Robots. We wanted the participants to rate the robot using the five Godspeed questionnaire from Bartneck et al. (2009). The UR10 robot we used is showed on figure 5.1 and gives an overview of the six joints on the arm.

Some weight balancing difficulties were found when mounting the LCD monitor on UR10 in this grounding study. Given the time frame for overcoming these difficulties it was decided to use a lighter temporary cardboard monitor with an image of the animated head attached which was mounted on the arm as to get a feel of the shape of the real AH.

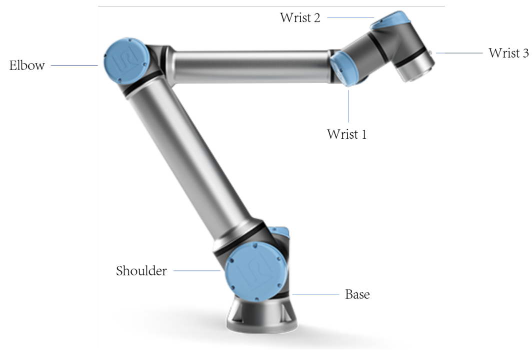


***Figure 5.1.*** A figure showing the UR10 robot arm used and name of its joints with 6 degrees of freedom. Original picture is from Universal Robots (`https://www.universal-robots.com/products/ur10-robot/` - Accessed 2019-04-07)

### Start positions

At first, two conditions were created with 8 similar movements, displaying a wide range of the movement capability of the UR10 robot. The main difference between the two conditions was the position of the Base joint and Wrist 2. We called the two different positions Front and Profile and they are both showed on Figure 5.2. The movements were created for the Front condition first and afterwards it was tried to mirror the same movements as close as possible in the Profile condition.

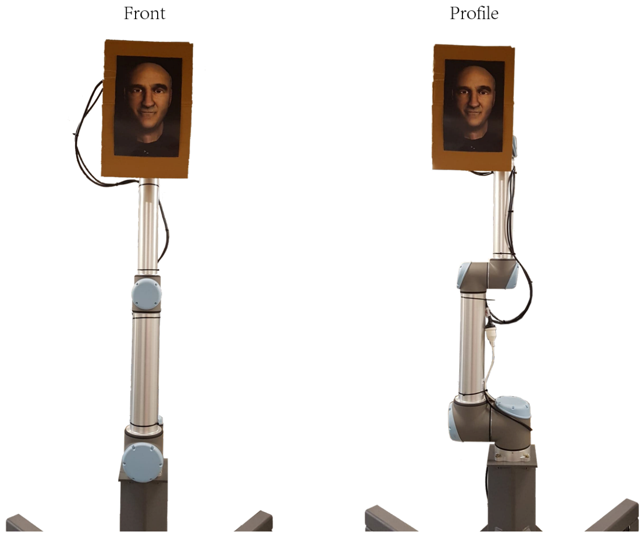


***Figure 5.2.*** Left is the Front position. Right is the Profile. Due to the joint positions, the Front can not bend towards the person, only sideways. The Profile has no issue bending forwards, but can not move to the sides.

In the Front condition, the Base joint and Wrist 2 was fixed in 0°, so that it looked straight ahead. In the Profile condition the Base and Wrist 2 were turned 90°(the joints now appeared in profile, but the head looked towards the person).

Having restrained the UR10 in a Front and Profile position limited its movements in certain directions. In the Front condition, this meant that the UR10 was unable to bend forwards to reduce its height to that of the participant. Instead it had to move down sideways. Whereas in the Profile condition, the UR10 was able to bend forwards, but not sideways. Minor movement adjustments had to be done, however, due to the mechanical shape of the UR10 and the size of the monitor. E.g. the monitor displaying the head could not turn very far to one side before inevitably colliding with the arm itself.

We discussed that the two movement conditions could favour the Front condition as this was the starting position from which the movements were created. Thus there might exist a movement bias. To combat this, we decided to create two new conditions where we started the movements from Profile and afterwards mirrored the movements to the Front condition. This meant that we turned out with four conditions to be presented to a small sample size of participants.

### The movement

Based on our literature review, we wanted to create dynamic movements with the robot. When changing the robot's position, we noticed that the UR10's movements seemed much more dynamic if we varied two or more joints at the same time. If only one were varied, the movement ended up looking very mechanic. This was interesting to us, so we decided to leave some movements in which were more mechanic from the others. Also, we introduced small pauses of 0.5-2 seconds in between the movements. It seemed to exert a better presence if it "lingered" at the end of some motions e.g. when at its closest to the participant. Finally, we lowered the speed from 100% to 65% as the movements appeared too quick at 100%. The original velocity and acceleration of the joint speed were set at v = 60 °/s and a = 80 $°/s^2$, meaning it was 65% of those settings.

### Presenting the movements to the participants

Four different movements were created, two based on the Front position (FF and FP) and two based on the profile position (PP and PF). The movements was named such that the first letter indicated the position that the movements were based on and the second letter was the position the robot was starting from when presented to the participant. E.g. Front-Profile (FP) means that the movements was initially created in the Front position but was presented to the participant in Profile.

Each participant was only presented with two of the four movements. We did not find it necessary that each participant was presented to all four movements, as long as all movements were presented the same number of times and each participant was presented to both Front and profile movements. This is possible to do, and still have a within-subject design because we only analyse the difference between the position the robot is moving from and not the position the movements is based on.

To balance the presentation of the movements, both in regards to the position from which the robot was moving, and the order the participants are presented to the movements, we had four different groups as shown in Table 5.1. We choose to have 16 participants in our study, four in each group. This made it possible to conduct the study in one day and have a small, but reasonable sample size for the analysis. As this was a grounding study we chose not to spend more than one day on the data collection.

| Participant | FF | FP | PP | PF |
|---|---|---|---|---|
| P01, P03, P05 & P07 | 1 | 2 | - | - |
| P02, P04, P06 & P08 | 2 | 1 | - | - |
| P09, P11, P13 & P15 | - | - | 1 | 2 |
| P10, P12, P14 & P16 | - | - | 2 | 1 |

***Table 5.1.*** How the participants were presented to the movements. The number in the table indicates in what order the participant was presented to the movements and "-" means that the participant was not presented to this movement. FF is Front-Front, FP is Front-Profile, PF is Profile-Front, PP is Profile-Profile.

## 5.2 Findings

Participants were recruited at UC campus in a study room next to the robotics lab where the study was conducted. 16 people participated in the study; 11 men and 5 female from the age of 19 to 50 (M = 24.4, SD = 7.6). The results from the study were based on the participants' answers to the five Godspeed Questionnaires.

### Reliability test on each concept

The Godspeed questionnaires are divided into five concepts; Anthropomorphism, Animacy, Likeability, Perceived Intellegence and Percieved Safety which are by Bartneck et al. (2009) found to be often-used concepts in HRI studies. The first four concepts are measurement of the participant's impression of the robot and the last one is rating of the participant's emotional state. The concepts measured with the Godspeed questionnaire, we interpreted as being important factors when wanting to create a convincing and engaging interaction with a social robot, which therefore makes the use of the Godspeed questionnaires relevant to this study and to our main studies.

Before we calculate the mean of Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety, a reliability test was conducted, which is good practise according to Bartneck et al. (2009). The raw data we conducted these tests on can be found in Appendix A.8. The Cronbach's $\alpha$ values from the tests are shown in Table 5.2.

| Concept | Front | Profile |
|---|---|---|
| Anthropomorphism | 0.86 | 0.81 |
| Animacy | 0.86 | 0.80 |
| Likeability | 0.90 | 0.80 |
| Perceived Intelligence | 0.79 | 0.85 |
| Perceived Safety | 0.58* | 0.57* |

***Table 5.2.*** Cronbach's $\alpha$ values for each of the five concepts. *These values are calculated for the inverted score on the last question (Quiescent/Surprised). The $\alpha$ values with the original scale orientation was -1.09 for Front and -0.12 for profile.

The $\alpha$ values presented in Table 5.2 are for the first four concepts in the ranges of 0.7-0.95, which is the range that Tavakol and Dennick (2011) found $\alpha$ values acceptable to be reported within. Tavakol and Dennick (2011) also recommended an $\alpha$ value less than 0.9, which all of the five values fulfills. The last concept about Perceived Safety had a $\alpha$ value of -1.09 for Front and -0.12 for Profile. According to A. Field, Miles, and Z. Field (2012, p. 930) a negative $\alpha$ value might indicate a reverse-phrased item. Looking at the statements for Perceived Safety, and the ratings given to each statement, it indicates that Quiescent/Surprised might be reverse-phrased compared to Anxious/Relaxed and Agitated/Calm. A new $\alpha$ value was calculated on each position based on the inverted ratings on Quiescent/Surprised these $\alpha$ values is 0.58 and 0.57 and are the ones presented in Table 5.2. The $\alpha$ values for Perceived Safety is still low, this might indicate poor inter-relatedness between items or heterogeneous constructs, it could also be because of a low number of questions (Tavakol and Dennick, 2011). The Perceived Safety concept only has three questions while the other four concepts have five or six, so this could be part of the explanation why the $\alpha$ values for this concept is lower than the others. Looking at the ratings for the items regarding Perceived Safety it might indicate that the data for Quiescent/Surprised is different than the data for the other two items. Because we concluded that there did not seem to be homogeneity between the items of Perceived Safety, this concept was not analysed based on the mean as the other four concepts were. Therefore we separated the analysis of Perceived Safety from the rest of the four concepts; Anthropomorphism, Animacy, Likeability, and Perceived Intelligence.

### 5.2.1 Perceived Safety

Instead of calculating the overall mean of Perceived Safety, the mean for the ratings on each item was calculated and is presented on Figure 5.3.

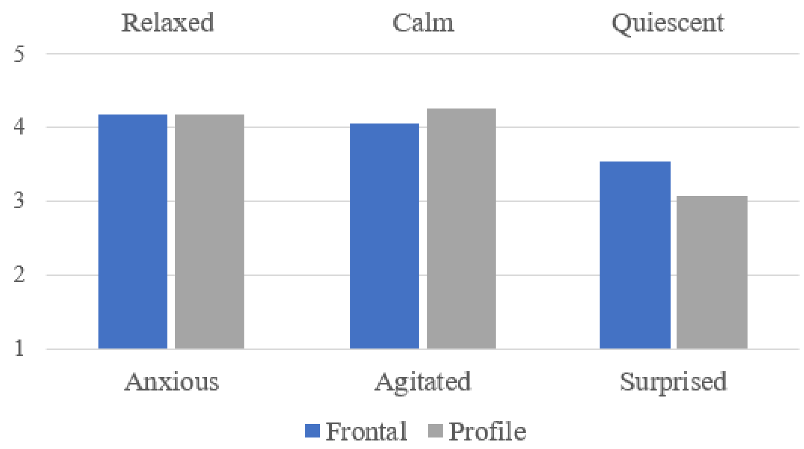


***Figure 5.3.*** Calculated mean for ratings on each position for the three items regarding Perceived Safety.

For the two first items, Anxious/Relaxed and Agitated/Calm, it seems as if the participants were more relaxed and calm than anxious or agitated. For the last item it seems as if the was more quiescent when presented to the robot in Front than the robot in Profile.

### 5.2.2 Anthropomorphism, Animacy, Likeability, and Perceived Intelligence

The mean is calculated for the four concepts with an acceptable $\alpha$ value , see Figure 5.4.

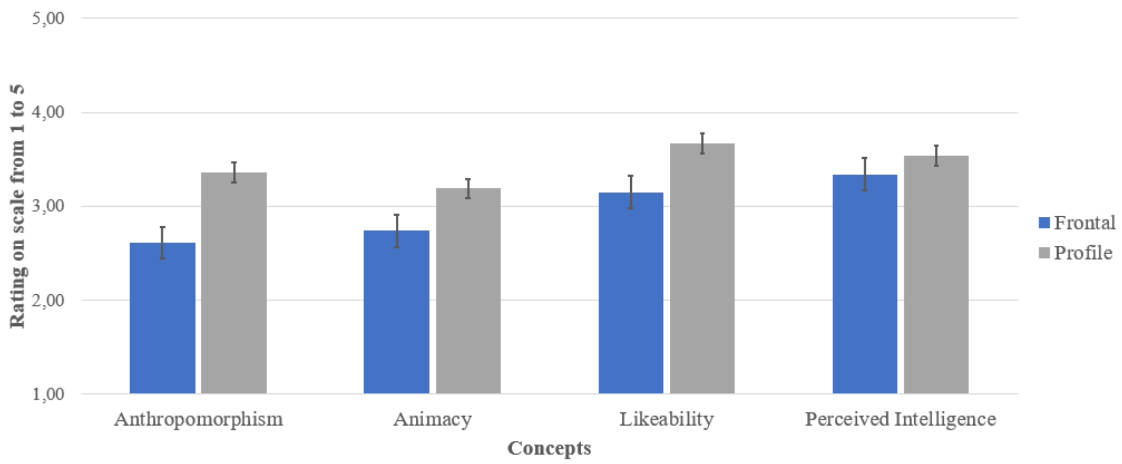


***Figure 5.4.*** Calculated mean and standard error for ratings on each position for the four concepts with an acceptable $\alpha$ value.

The calculated means indicated that the robot in Profile on average was rated higher on all four concepts compared to the robot in Front position. To look at more than just the mean of the ratings, a boxplot was created for each of the four concepts, these boxplots is presented in Figure 5.5.

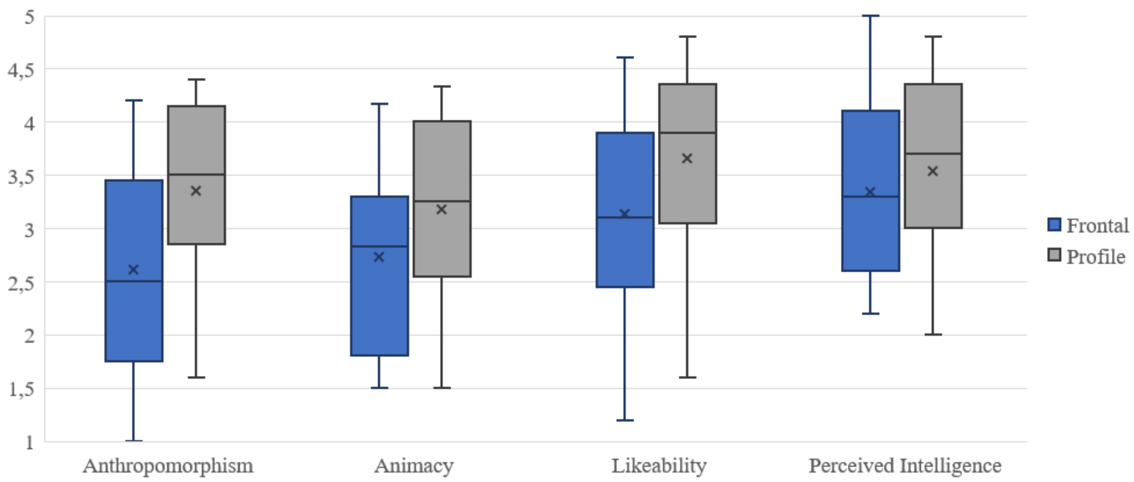


***Figure 5.5.*** Boxplot for ratings on each position for the four concepts. The X is the mean for the ratings.

The boxplots on Figure 5.5 could indicate that there is a difference between the ratings of the robot in Profile and Front for Anthropomorphism, Animacy and Likeability, but it is not a clear difference because the overlap between the ratings is still big. Based on the two boxplots for Perceived Intelligence, it seems unlikely that there is a difference between the ratings of Front and Profile as they appear similar.

In order to investigate if there was a significant difference between the ratings of the robot in the two different positions, a statistic analysis was conducted. The R script for the conducted analysis can be found in Appendix A.9.

We chose to conduct a Multivariate analysis of variance (MANOVA) based on our data and study design. We had one independent categorical variable which was the position of the robot (Front or Profile). We had four dependent variables which were the four different concepts, they all have same type of data, which is the average of each person's rating for the items of each concept. The dependent variables are treated as continuous.

MANOVA is a similar analysis to Analysis of variance (ANOVA), just for dataset with several dependent variables (A. Field, Miles, and Z. Field, 2012, p. 819). We could just have conducted an ANOVA on data for each concept (each dependent variable) but the reasons why we chose to do a MANOVA instead was that there is a smaller chance of making Type I Errors and a MANOVA makes it possible to look at relationships between the dependent variables (A. Field, Miles, and Z. Field, 2012, p. 821).
The analysis was conducted in R and the script can be found in Appendix A.9. Before the MANOVA was conducted the assumptions for the test was checked.

There are four assumptions for the MANOVA (A. Field, Miles, and Z. Field, 2012, p.840):
1. Independent observations
2. Random sampling
3. Multivariate normality
4. Homogeneity of covariance matrices

The first two assumptions were met in the way we conducted the study. In order to check for multivariate normality, we tested with a Shapiro-Wilk normality test, and we checked the assumption of Homogeneity of Covariance Matrices by calculating the matrices and comparing them.

The results from the Shapiro-Wilk normality test for Front is $W = 0.875$, $p = 0.033$ and for Profile $W = 0.866$, $p = 0.023$. Both results show that they are significantly non-normal, which means that the third assumption was not met. Addressing that the assumption of multivariate normality was not met can be done in different ways, one way is to look for outliers and exclude them from the data. As this is only a grounding study, which serves as preliminary work for the main study it is chosen not to address this unmet assumption and conduct the MANOVA even though we know that the results would not be conclusive. Be conducting the analysis we got familiar with this analysis which we expected to be useful in the analysis of the main studies.

To test the fourth and last assumption for the MANOVA we looked at the Covariance matrices for Front and for Profile presented in Table 5.3 and compared the two matrices.

**Front**

| | Anthropomorphism | Animacy | Likeability | Intelligence |
|---|---|---|---|---|
| Anthropomorphism | 1.037 | 0.827 | 0.694 | 0.590 |
| Animacy | 0.827 | 0.855 | 0.540 | 0.454 |
| Likeability | 0.694 | 0.540 | 1.044 | 0.692 |
| Intelligence | 0.590 | 0.454 | 0.692 | 0.708 |

**Profile**

| | Anthropomorphism | Animacy | Likeability | Intelligence |
|---|---|---|---|---|
| Anthropomorphism | 0.766 | 0.575 | 0.327 | 0.257 |
| Animacy | 0.575 | 0.731 | 0.305 | 0.274 |
| Likeability | 0.327 | 0.305 | 0.771 | 0.242 |
| Intelligence | 0.257 | 0.274 | 0.242 | 0.767 |

***Table 5.3.*** Covariance matrices for Front and Profile.

When comparing the two covariance matrices we looked at variance for each concept compared between Front and Profile, these are the values presented diagonal in the matrices on Table 5.3. The one with the highest variation is Likeability with a difference of 0.273 between Profile and Front. The other elements we compared was the covariance presented in the off-diagonals on Table 5.3 where the highest variance is Likeability/Perceived Intelligence with a difference of 0.45. A. Field, Miles, and Z. Field (2012, p.849) states that the threshold that is should be under preferably is 2. This means that the assumption homogeneity of covariance matrices is meet.

For MANOVA there are four different test statistics. We chose to conduct and report the Pillai–Bartlett trace as it was the most robust test when assumptions are violated, which we had for Multivariate normality where the Shapiro-Wilk test showed that the assumption for multivariate normality was not met (A. Field, Miles, and Z. Field, 2012, p. 842). Using Pillai's trace, we did not find that there was a significant effect of the position of the robot on the ratings of the robot for the four different concepts, $V = 0.17$, $F(4, 30) = 1.36$, $p = 0.27$. However, conducting separate univariate ANOVAs on the outcome variables revealed significant effect of the position on the rating of the Anthropomorphism of the robot, $F(1, 30)$ 4.87, $p = 0.035$, but no significant effect of the position on the rating of the three other concepts, Animacy $F(1, 30)$ 2.04, $p = 0.16$, Likeability $F(1, 30)$ 2.37, $p = 0.13$ and Perceived Intelligence $F(1, 30)$ 0.43, $p = 0.52$. It is important to keep the assumption violation in mind when interpreting these results from the analysis.

## 5.3 Sub-conclusion

The item Quiescent/Surprised from the Perceived Safety concept seems to be inverted and some people did not understand the word Quiescent. We therefore suggest changing the wording and inverting them for the main studies.
The statistic analysis showed significant effect of the position on the rating of the Anthropomorphism of the robot, $F(1, 30)$ 4.87, $p = 0.035$ but the assumption of multivariate normality was not met which makes the analysis less reliable.

From the findings of this grounding study we see a tendency that the robot with the base in Profile position was perceived more anthropomorphic, had higher animacy, was more likeable and perceived as more intelligent. This was also indicated by the comments from the participants, where one stated that he found the robot in Profile more friendly in Profile than when it was in Front and one commented that it seemed more engaging when it was in Profile. We therefore recommend to have the base in Profile position to get a more convincing and engaging interaction with it.

# 6 Research Design for Main Studies

Two main studies were conducted in different settings to address the problem formulation; one in the wild at an event at UC campus and one in the Lab at the Human Observation Laboratory at the Human-Centered Technology Research Center at UC. A single research design was developed with the goal of conducting two studies in different settings with as similar research design as possible in order to be able to compare the findings between the studies afterwards.

## 6.1 Context and Group Interaction

We had two different settings: in the wild and in the lab. We changed the setting but instructed the participants to imagine that they were in a science museum interacting with an exhibition. This was done in an attempt to make sure that the context did not change, only the setting and thereby addressing our research question *1.How do participants interact with the AH in the context of a Science Museum?*. It was also done to give the participants some purpose of the interaction with the robot.
Part of the interview post interaction was conducted in order to explore other contexts where the participants might see this specific robot being used.

Based on our interview with the curatorial team (see Appendix D) and the general context for the robot was a science museum, we decided to study groups rather than individuals, as we found this to be the most common way of interacting with exhibits and the Articulated Head when its going to be installed at Questacon. We found group interaction to be an important factor to take into account and implement in the research design. We therefore tried to find groups of people when recruiting participants. This also addresses our sixth research question *6.How can the group dynamic found between visitors at a science museum be implemented in the study?*.

## 6.2 The Robot Movements

Based on the results from our grounding study, we designed some new movements for the robot. The grounding study results showed a tendency that people preferred the movements designed from the Profile position. We therefore based our new movements off of that and, tried to implement what particular movements had worked the best. In the grounding study, we conducted the test using a light-weight card board prototype of the monitor with a printout of Stelarcs animated head. This was done because the robot initiated a protective stop at times when the real monitor was mounted on it. We suspect this was due to the monitor not being equally balanced around the centred mount and the UR10 then sensed external forces was acting on it when moving. We could not program the centre of gravity precisely enough to eliminate the protective stops in time for the main studies, so we were constrained to movements that would not trigger the protective stop and would allow the robot to run its movements in a loop.

We displayed the 3D animation of Stelarc's head on the monitor, which had pre-programmed movements of its own. These included the eyes scanning, the head turning from side to side, and the head tilting as well. The animation of the head is showed on Figure 6.1.

***Figure 6.1.*** A still shot of the facial animation depicting the performance artist, Stelarc. This is what we presented to the participants. Picture used with permission from Questacon.

We consulted Dr. Elizabeth Jochum when finalising the movements and she was able to give us great suggestions on where to implement pauses in order to create a more powerful or meaningful movement. The whole set of movements consisted of 12 waypoints and one loop lasted 1 minute and 25 seconds. As mentioned in the grounding study, Chapter 5, we found that changing more than one joint position, from one waypoint to the next, created a much more dynamic movement which we wanted to implement, as this is something that the Articulated Head strives to achieve in its final version. It is also in part based on the recommendations from Hoffman and Ju (2012), which was kept in mind during the design of the movements.

## 6.3 Data Collection

With our research question regarding *4.How can a mixed method approach be implemented in an HRI study conducted in different settings?* in mind we made decisions on what data we wanted to collect and which methods we would use. We chose to have a mixed method approach where we would collect both self-reported data and observational data which we found in our literature review to be preferable. The advantages of having a mixed method approach is that it gives the possibility to compare findings from the qualitative and the quantitative data and thereby getting more nuanced findings based on the different perspectives.

### Interview prior to interaction with robot

The purpose of the interview prior to the interaction is to understand the participants' general opinion and perception of robots which we found through the literature review to be an important factor.

The interviews were audio recorded and were conducted after the participants agreed to participate and had signed the consent form. The questions prepared for the interview was:

1. How would you define a robot?
2. How would you describe your general attitude towards robots?
3. Do you see any differences between robots in the home, workplace, education, or hospitals?
4. Do you think there are some places where robots shouldn't be?
5. Do you think there are places where robots should replace humans?

### Video recording of interaction

We decided to video record the participants' interactions with the robot in order to be able to analyse their reactions to the robot and their behaviour around it. We decided to have two camera angles: a bird's eye view from behind looking towards the robot, and a frontal camera placed behind the robot aimed at capturing their facial expressions and gaze.

### Godspeed Questionnaires

Like in the grounding study, we utilised the Godspeed questionnaire for their rating of the robot, that measures the participants perception of the five concepts; Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety (Bartneck et al., 2009). These five concept we found relevant when wanting to understanding the HRI and are all interesting to explore in regards of the effect of setting on the perception of each concept. Through the literature review on how to measure HRI it was found that the five Godspeed Questionnaires by Bartneck et al. (2009) would be a good tool for measuring the HRI. We also find the concepts in the five Godspeed questionnaire to be important when wanting to create a convincing and engaging interaction with a social robot which was the goal according to our problem formulation. It therefore makes the concept relevant to measure so we get an indication of how convincing and engaging the participants found the interaction with the robot to be.

However, based on experience from the grounding study in lab, we decided to revise the questionnaire slightly. We removed the translations of the individual factors and removed the concept titles Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety. Also, due to the results of reliability test in the grounding study in lab we decided reverse the last item in Perceived Safety while also changing the word

"Quiescent" to "Unsurprised", based on comments during the grounding study in lab. See Appendix E for the original Godspeed questionnaire and our slightly revised version. The questionnaires were administered using tablets and the participants were asked to answer the questionnaires individually right after they ended the interaction with the robot.

### Interview post interaction with robot

After the participants rated the robot, we conducted an interview where the purpose was to get the participant to describe how they experienced the interaction with the robot. Another purpose of this interview was to explore other contexts where the participants could imagine the AH to be used to address our research question *5.How might we explore possible contexts the AH could be implemented in?*. Exploring the possible contexts can be important and valuable in regards of the further development of the AH and conducting studies where the effect of relevant context is investigated, this was done by asking the participants where they could see the robot in use. The findings regarding where the participants could imagine the AH to be used is listed in Appendix G and not further analysed.

We asked the participants about their experience while they were situated in front of the robot, to make it more convenient for the participants and so they would be able to use the robot to recall any experiences. This interview was audio-recorded and the questions asked during the interview were:

1. First of all I would like you to describe your impression of the robot.
2. What was important to you when you interacted with the robot?
3. Tell me about your reactions to the robot.
4. What would you have liked the robot to do?
5. If at all, where could you see this robot in use?
6. Could you imagine this robot at home?
7. How would you describe the intelligence of this robot to be?
8. How would you expect the robot to move or behave if it was alive?
9. Of the things we have discussed, what to you is the most important?

### Focus Group Interview

We designed the session in the lab to function as a small focus group interview with professionals within ergonomics from the Human Factors & Ergonomics Society of Australia (HFESA) (`https://www.ergonomics.org.au/`). The focus group was conducted after the participants had interacted with the robot and the interview post interaction with robot was conducted. The purpose of conducting the focus group interview was to utilise the expertise of the participants because they had experience and knowledge about researching Human Machine Interaction (HMI) which we find to be relevant, because there might be several things these two areas of research has in common.

According to Krueger and Casey (2002) there are four imortant factors to conducing a good focus group. The first one is to carefully recruit the participants and reflect on why they are relevant to interview. The second is to conduct the focus group interview in a comfortable environment so the participants are comfortable to engage in discussions. The third is to have a skillful moderator lead the interview. Fourth and last factor is to follow the interview with systematic analysis and reporting.

In the design of our focus group we addressed all of the four factors to some extend within the limitations that we dealt with. We chose to use people within ergonomics in our focus group to be able to use their specialised knowledge in order to further the development of the AH and explore where they might see this robot in use. They knew each other professionally prior to participating in the lab but we were not able to gauge how their intergroup dynamic was prior to participating in the study, which can be seen as a limitation. The group was chosen because they might have some interesting insights into natural kinematics, that could aid the perceived agency and animacy of the robot, much like Heider and Simmel (1944). Also, they might bring some considerations regarding human machine interaction that was overlooked previously. The location for the interview was in the lab, where we set up some sofas and had some refreshments ready for the participants in order to create a peaceful environment. The moderator had prepared an interview and had following questions ready to ask the participants:

1. Can I get you to explain your work to me.
2. How, if in any away, can you relate your experience with this robot to your work and expertise?
3. How might robots in general be relevant to your work?
4. What factors are important in your work if you were to study interactions with a robot like this? And how would you study these factors?
5. How would you normally conduct studies within human factors?

The last factor of systematic analysis and reporting is yet to be addressed in a thorough manner as there was not enough time to conduct a full analysis of all the data collected in the main study and in lab.

## 6.4 Ethical considerations

As part of doing research in another country than Denmark, we learned the process of getting ethical approval before conducting any studies with human participants. This requirement for Ethical approval by University of Canberra inspired some relevant reflections about the ethics when conducting a study with human participants, the main actions on these considerations are presented in the following section. The granted ethical approvals for the main studies can be found in Appendix A.6.

### Consent

Before participating in the studies, all participants were instructed to read the Participant Information Form and Consent Form, presented in Appendix A.7. The consent form has six check boxes that asks the participant to consent to being audio recorded, being video recorded, participate in an interview with the researcher, being observed while interacting with the robots, give permission that the data collected may be used in future projects and give permission to their picture being used in future research publications/presentations.

### Contact after participation in study

All participants were offered to keep the Participant Information Form, see Appendix A.7. This form has the contact information of the main research and makes it possible for the participants to inquire more about the research or revoke their consent.

### Voluntary participation

To make sure the participation was voluntary, the participants were informed by the start of the study that they were free to withdraw and walk away at any given point without having to explain why and that there would be no consequences if they chose to withdraw from the study.

### Safety

In regards to safety at both settings, a researcher was standing with the control panel and a hand on the "E-STOP" at all times when the robot was running. At the UC event it was necessary to consider safety precautions to make sure that no one would be injured by the robot. A table was placed behind the robot as a natural barrier, to make it more difficult to walk up behind the robot and ensured that the interaction happened in front of the robot. We also made a line with yellow tape on the floor indicating the robot's reach, the people crossing this line would be within the area where the robot could touch them. The participants were instructed and observed in order to make sure the robot would not injure them. If some people at the event got close to the robot they would get the safety instruction:

> Just for safety - the robot is not programmed to stop. My colleague in the corner will manually stop it if it is necessary. And just let her/him know if you find it necessary.

## 6.5 Analysis of Data

Since we used a mixed method approach, it meant that we had both quantitative and qualitative data that was analysed. The quantitative data was collected through the five Godspeed questionnaire and the qualitative data was the video and audio recordings along with general notes. We here outline which methods we used in order to draw conclusions on the findings from the data collected in the studies.

### 6.5.1 Analysis of data from the Godspeed Questionnaires

As the sample size for the main studies was to small we chose not to do conduct a statistic analysis. If the sample size had been bigger we would have conducted a MANOVA following the same approach as we did on the data from the grounding study in lab. See Chapter 5.

Instead, the quantitative data from the main studies were plotted, and the means were calculated while we looked for tendencies, but no definitive conclusions could be made based on the data, only indications, tendencies and reflections on the applied methods. Focus will therefore be on the qualitative part of the analysis.

### 6.5.2 Thematic Analysis of Video and Audio recordings

The qualitative data collected at the UC event and in the lab was analysed to understand how the participants interacted with the AH and how they experienced the interaction to address the two research questions *1. How do participants interact with the AH in the context of a Science Museum?* and *2. How do participants experience interacting with the AH?* and thereby get findings to address our problem formulation by comparing the findings from each study. We conducted two Thematic Analysis for each of the studies which is a qualitative analytic method usually applied within psychology that search for themes and patterns across the data. Braun and V. Clarke (2006) defined thematic analysis as a method for identifying, analysing and reporting patterns (themes) within data. It minimally organises and describes ones data in rich detail. Thematic analysis usually involves showing the ontology of the data i.e. map the data and how it connects together in a theme map. As many other qualitative methods (Content analysis, Discourse analysis, interpretative phenomenological analysis etc.) it is a recursive method which means that one always have to go back and forth between the whole data set and see whether or not ones codes need to be re-coded. It is a time consuming method and should not be rushed. We followed the 6-step guide proposed in Braun and V. Clarke (2006) but decided to apply the method on our video recordings as well.

One analysis on the video recordings and one on the audio recordings. We followed the thematic analysis steps presented in Braun and V. Clarke (2006) and occasionally followed recommendations presented in Derry et al. (2010). We focused our analysis around what the participants did in relation to their interaction with the robot. In the interview we would include data when they were talking about the robot. When analysing the video, we would only focus on the interaction. While conducting the analysis, we started the write up that is presented here. This also helped us reflect on the method used and is recommended by Braun and V. Clarke (2006) to do.

#### Video coding

We started out by coding participants' behaviour on the videos and afterwards coding their statements in the interview. For the purpose of coding, we utilised the briefing room at UC which had a big screen and allowed to more easily code the videos together. Preferably one would use a bigger group reviewing the videos and taking part in the analysis, but this analysis was only done by the the two authors. We started out by viewing every participant video while taking notes to create a content log which is recommended by Derry et al. (2010). This also served to familiarise ourselves better with the collected data to minimise unjustified assumptions (Braun and V. Clarke, 2006).

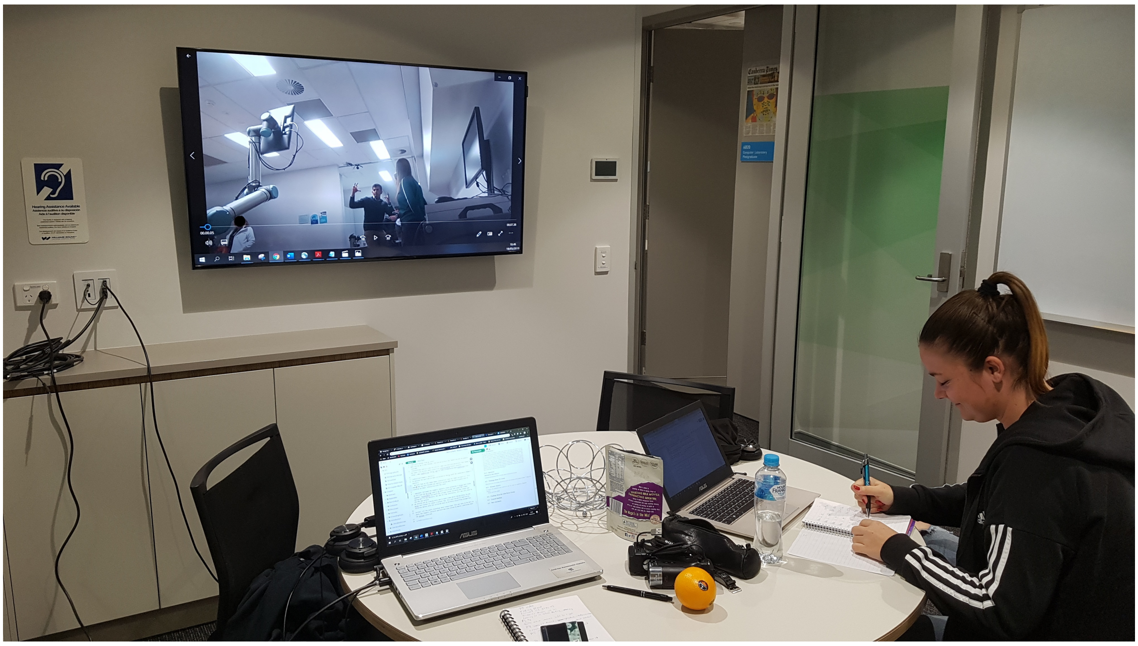

***Figure 6.2.*** The video code setup in the briefing room.

Due to the coding process being a very time consuming process, we decided to only analyse the video recording of the front of the participants, while the recording from behind the participants was used in cases where we were unsure of the interpretation of the participants actions in which the front of the robot might give some input as to why the participants acted as they did.

### Interview coding

As a preparation to the coding process, all the audio recordings were transcribed. This was done to be able to apply the thematic analysis approach and also served to better understand what the data set contained. Before any coding, we put the transcriptions on the big screen and listened to the interview in its entirety. This way the data was fresh in mind, and the meanings and context of the statements, easier to analyse. Afterwards we listened again and began coding. When coding the transcribed interview, we used the comment function in Microsoft Word. This served to clearly show which statement contributed to which code. It was also possible to easily extract the comments to be printed out and physically rearranged.

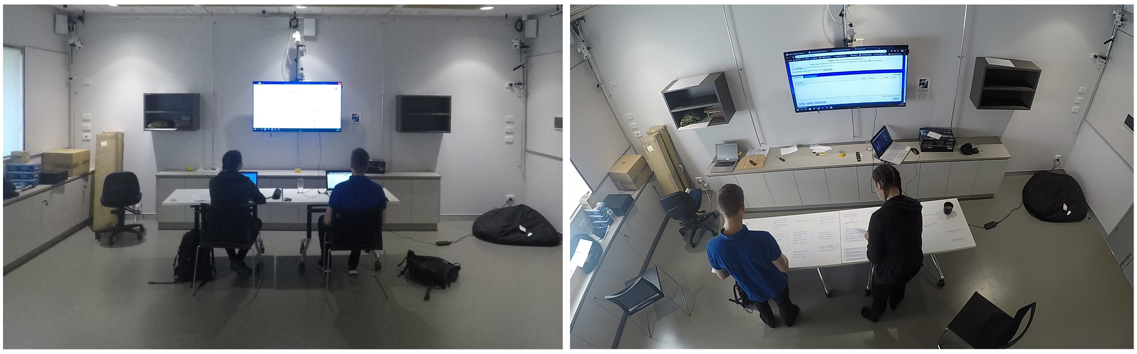

***Figure 6.3.*** Pictures showing the sorting process in the thematic analysis. The left picture depicts when we would listen through the audio file while reading the transcript and creating the codes. The right picture is how we sorted the codes.

When we were done with the initial coding we then grouped the codes and created focused codes which then finally were categorised in major themes, which is the final results of the Thematic Analysis. We chose to create theme maps as well. Theme maps are basically just a visual representation of how ones data and codes are connected across the whole dataset. The themes are usually represented by ovals where the focused codes, that make up a theme, are rectangles. It helps provide an overview of the data.

# Main Study in the Wild at UC Event 7

A series of unexpected legal and technical obstacles shifted the timeline of the project. This worked against our favour and meant that we would not be able to conduct the planned studies at the Questacon exhibition space within our limited time-frame that is the 10th semester of the Engineering Psychology education. Therefore, we had to adapt to the situation in order to obtain data from an in the wild setting to be able to address our problem formulation. This meant that we set up the robot at a student event on UC campus and recruited students participating the event on site.

## 7.1 UC event as setting for study

We utilised a student event on UC campus in Building 1, May 10th - 2019. The event was showcasing collaborations between UC and industry. The Articulated Head was brought from the lab and installed at the event close to where the presentations were held. See Figure 7.1 for a schematic and Figure 7.2. We set up a table close to the robot and recruited small groups of people (1-4) to resemble how people are expected to interact with the robot at Questacon. We also informed them that this robot will be an exhibition at Questacon, The National Science and Technology Centre. This was done to make sure, that they understood the context. After the interaction (2-5 minutes), the group was asked to individually rate their impression of the robot using the Five Godspeed questionnaire on provided tablets. After they have completed the Godspeed questionnaire, we asked them a few questions about their interaction. The original and our revised Godspeed questionnaire used can be seen in Appendix E. The interview questions can be seen in section 6.3 and section 6.3.

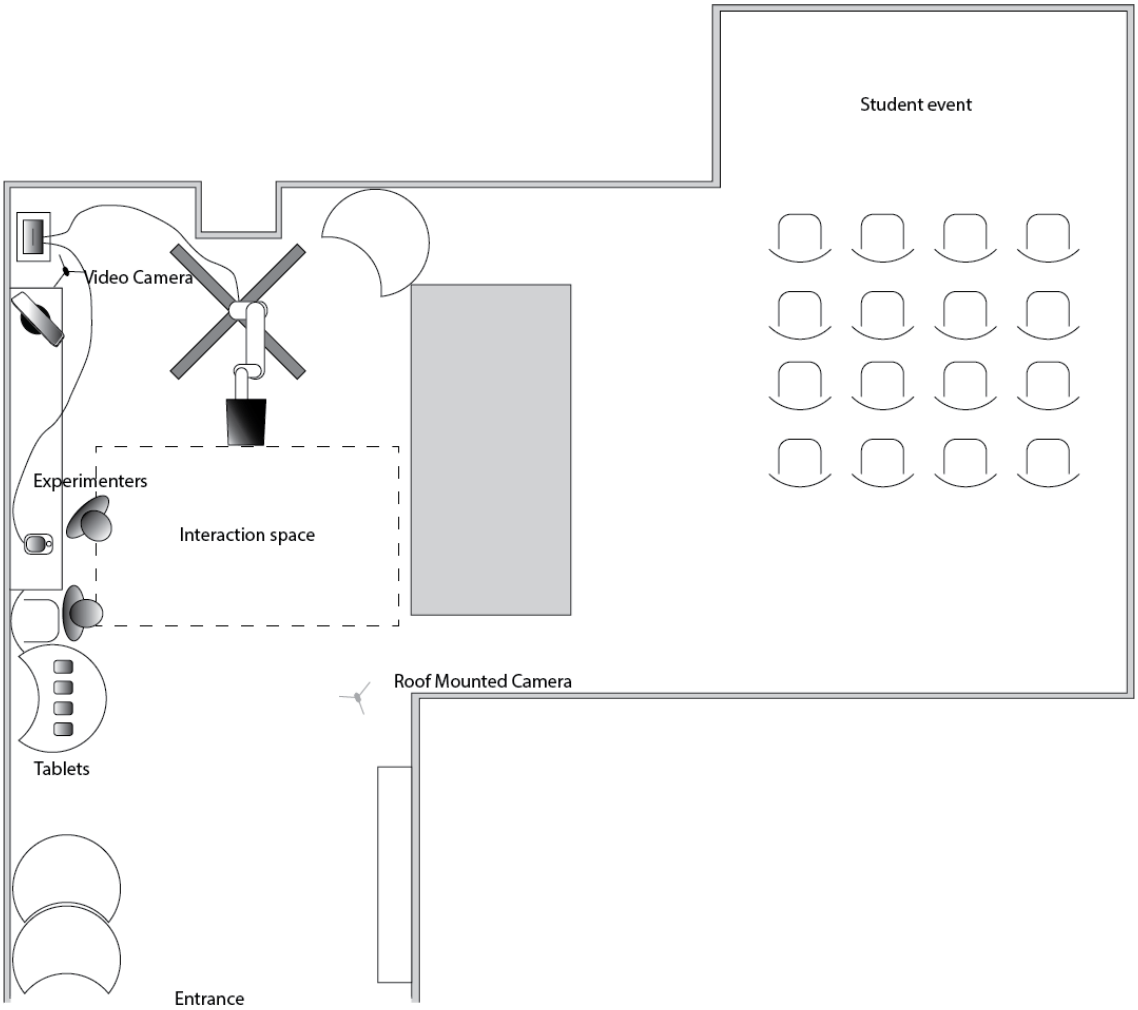


***Figure 7.1.*** The ground floor of the student event where the study took place. The AH was positioned so everybody attending the event passed it on the way in. A camera was placed behind the robot capturing the participant's facial expressions and a roof mounted camera was placed behind the participants in order to have a birds eye view of the interaction.

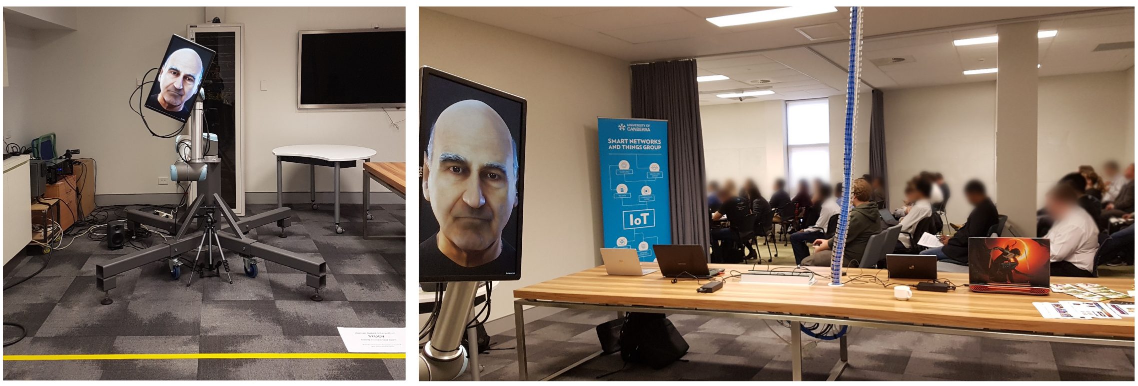


***Figure 7.2.*** How our setup looked at the UC Student event. Left is what the attendees saw when entering the event. Right is showing the event during a talk.

## 7.2 Findings from Quantitative data

All participants answered the Godspeed questionnaires right after they had interacted with the robot this gave us 10 ratings on 24 items that can be divided into five concepts; Anthropomorphism, Animacy, Likeability, Perceived Intelligence and Perceived Safety. we conducted a reliability test to see if it was meaningful to calculate the mean for each of the five concepts.

### Reliability test on each concept

Before the mean of Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety are calculated a reliability test was conducted, which is good practise according to Bartneck et al. (2009). The Cronbach's $\alpha$ values from the tests are shown in Table 7.1

| **Concept** | $\alpha$ |
|---|---|
| Anthropomorphism | 0.62 |
| Animacy | 0.76 |
| Likeability | 0.46 |
| Perceived Intelligence | 0.39 |
| Perceived Safety | 0.59 |

***Table 7.1.*** Cronbach's $\alpha$ values for each of the five concepts.

Only the $\alpha$ value for Animacy presented in Table 7.1 is within the ranges of 0.7-0.95, which is the range that Tavakol and Dennick (2011) found $\alpha$ values acceptable to be reported within. The other four concepts are all below 0.7 which indicates low internal consistency, which means that the items only to a low extent measures the same concept. Based on the calculated $\alpha$ values, it was decided not to analyse the mean of the concepts but the items individually. Even though the mean was not calculated we still divide the further analysis in the five concepts and look at the individual items for each concept.

### Anthropomorphism

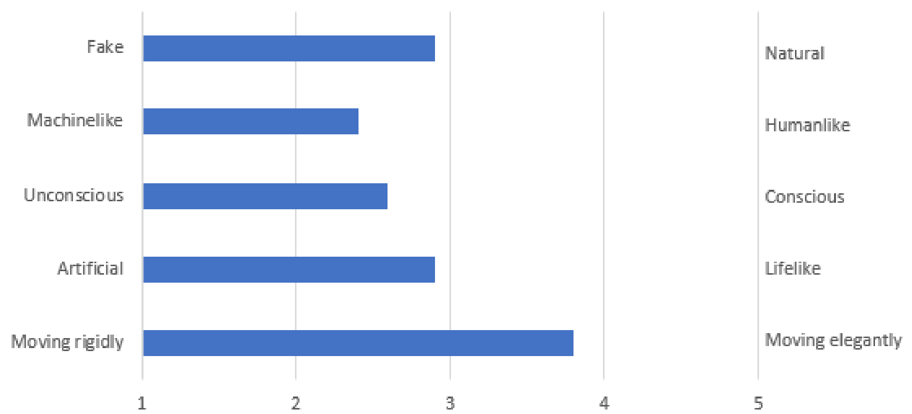


***Figure 7.3.*** Average rating on each item regarding Anthropomorphism at the UC Event.

The mean for each item regarding the concept anthropomorphism is showed on Figure 7.3.

The scale item within anthropomorphism that has the highest mean is Moving rigidly/Moving elegantly this is interesting when taking into account that it was the Articulated Head which the participants were rating. For AH it could indicate that the robot moving elegantly, or maybe even human-like, does not make the participants think of the robot as being more anthropomorphic. This could be relevant to explore in relation to what it is that is moving on the robot. For the Articulated Head it is a face on a robot arm. For some other robots the "body" of the robot is more anthropomorphic by it self, which could attribute to dynamic movements being perceived differently than what our findings indicate here.

### Animacy

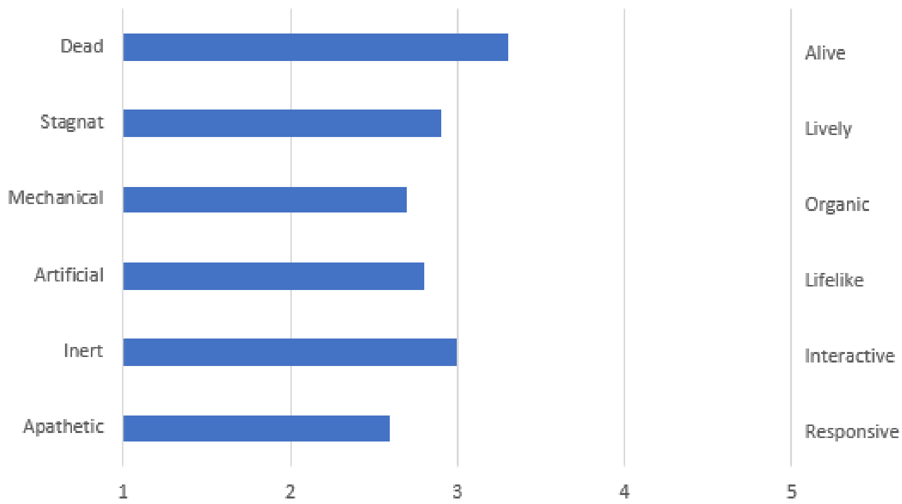


***Figure 7.4.*** Average rating on each item regarding Animacy at the UC Event.

The only concept with a Cronbach's $\alpha$ value within the acceptable range is Animacy. The mean for this concept is calculated and is 2.88, which is very close to the middle of the scale it was rated on, which is 3. The mean for each item regarding Animacy was also calculated and showed on Figure 7.4. The means for all six items are around the middle of the scale as the mean for animacy also is.

The robot was rated more apathetic than responsive, but that was expected, because the robot was moving in a predetermined loop of movement and without sensing of the surroundings. Also, we suspected that the facial expressions of the robot might have contributed to this rather apathetic rating i.e. never smiling etc.

### Likeability

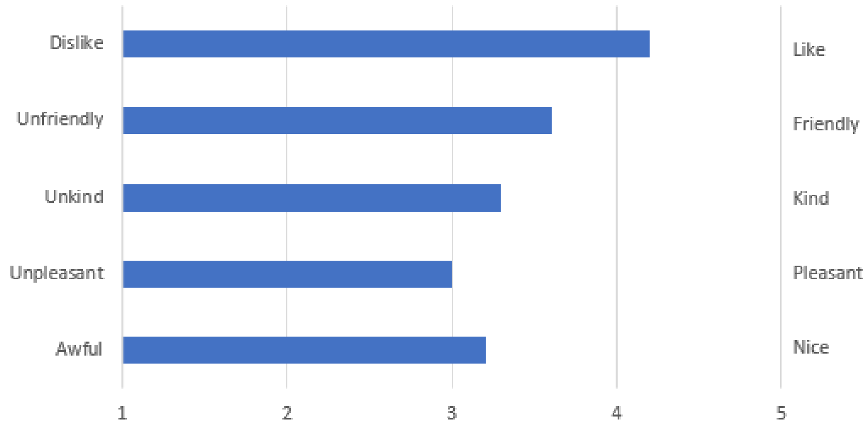


***Figure 7.5.*** Average rating on each item regarding Likeability at the UC Event.

On Figure 7.5 the mean for the items regarding Likeability is presented.

The item rated the highest was Dislike/Like which indicates that the participants liked the robot. This also fits nicely with their ratings also showed a tendency towards perceiving it more friendly than unfriendly. The average rating for the scale item Unpleasant/Pleasant is right in the middle which might indicate that, despite liking the robot and leaning towards it being friendly, they still do not quite know how to feel about it.

### Perceived Intelligence

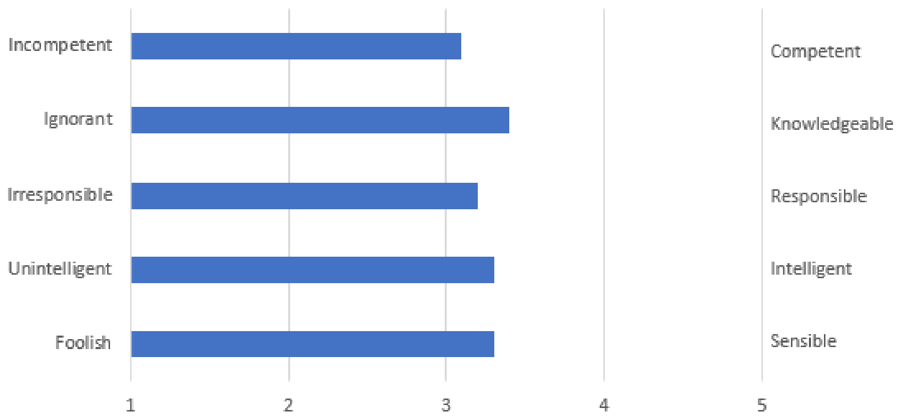


***Figure 7.6.*** Average rating on each item regarding Perceived Intelligence at the UC Event.

For the concept Perceived Intelligence the mean of the items is presented on Figure 7.6.

All means for the items are are a little over the middle. It indicates that the participants thinks the robot has some intelligence, but not much.

### Perceived Safety

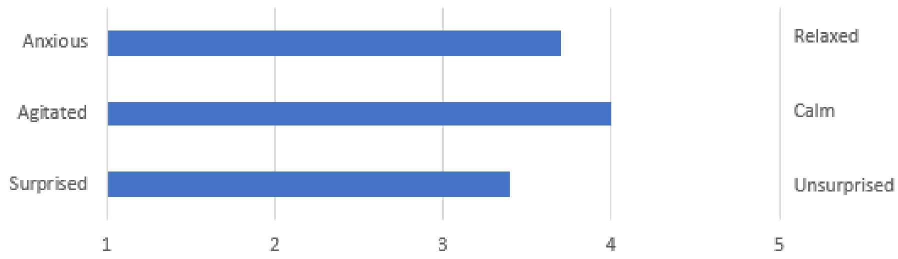


***Figure 7.7.*** Average rating on each item regarding Perceived Safety at the UC Event.

The concept regarding Perceived Safety has three items that all are ratings of the participants emotional state and not impression of the robot as the first four concepts was. On Figure 7.7 the mean for the ratings on each item is presented.

The overall impression when looking at the means for the items regarding Perceived Safety is that the participant seems to feel safe around the robot.

## 7.3 Findings from Qualitative Data

In total, 10 persons; 9 male, 1 female, age range 23-60 (M = 24.2, SD = 12.1) agreed to participate at the UC event which was fewer than expected. We video recorded their interactions from two different angles in order to capture their facial expressions, their reactions to the animated face, and their overall movement around the interaction space. We audio recorded their interactions and subsequent interviews. We chose to use a Thematic analysis of the video- and audio data. We followed the method described by Braun and V. Clarke (2006) as we describe in section 6.5.
The transcription including codes of the audio data can be found in Appendix A.10 and the video codes can be found in Appendix A.11.

### 7.3.1 Themes

When we were done with the initial video codes, we had 63 initial codes tied to their behaviour and interaction with the robot. These codes were grouped into 11 focused codes and were finally categorised into 3 major themes. See Figure 7.8 and Figure 7.9.

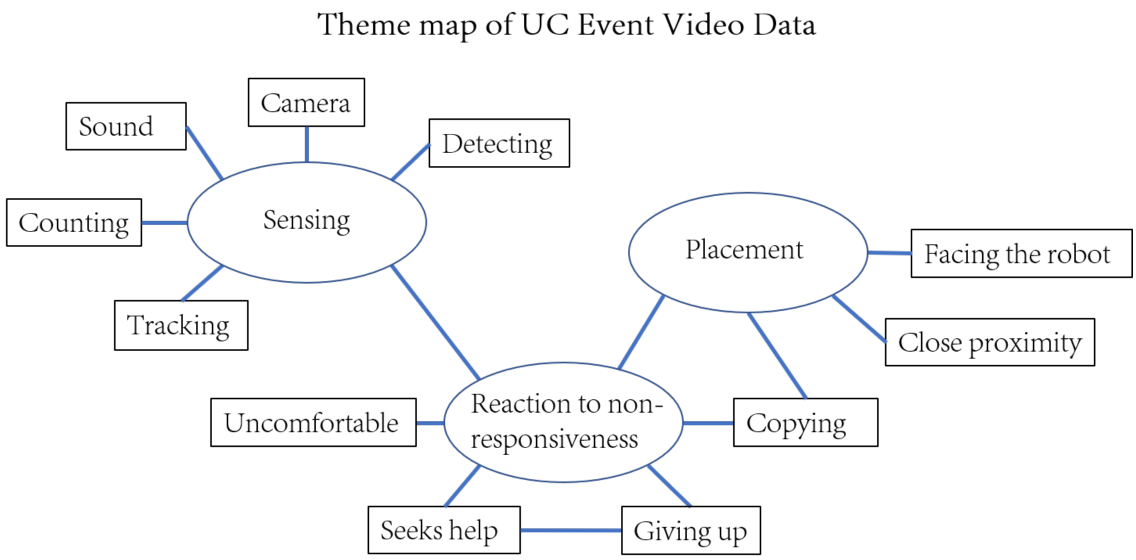


***Figure 7.8.*** Theme map from the UC event, based on the video analysis. The ellipses represent the major themes and the rectangles the focused codes. We drew a line where we believed they were connected based on the codes.

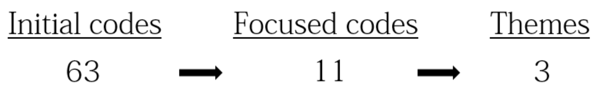


***Figure 7.9.*** Shows the procedural steps to the themes when coding the video data: 63 initial codes turned into 11 focused codes which created 3 themes.

When we were done with the initial interview coding, we had 114 initial codes. These were grouped into 21 focused codes which then finally were categorised in 7 major themes:

- **Disconnect between face and arm**
- **Connection between human and AH**
- **Lack of interaction**
- **Understanding AH**
- **Impression of AH**
- **Positive**
- **Robo-ethics**

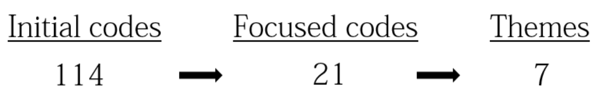


***Figure 7.10.*** Shows the procedural steps to the themes when coding the interview data: 114 codes were initially created, which were grouped into 32 focused codes, and created 10 themes.

A thematic map was produced to help with this process how the themes relate to each other, but was too big to be shown here. It is presented in Appendix F. Also, see Figure 7.10 for a procedural overview of the coding process.

### Sensing

The Sensing theme was derived from the various strategies that the participants utilised during their encounter with the robot including greeting it verbally with a hello and seeing whether or not it would react to sound coming from the side. They also tested the robot's tracking abilities by moving their bodies around, trying to elicit a response. Some tried to identify a camera on the screen in order to figure out how or if it was sensing. They also tried to follow the virtual gaze to try and identify what object of interest the robot might have found, and could have caused it to move. Many performed gestures close to the screen and the animated eyes as well.

### Placement

The Placement theme describes how the participants positioned themselves around the robot. The face of the AH held a lot of power, as the participants' attention was drawn to it and the eyes especially. If the robot moved to the side, they would shift their position so as to retain their view of the face. People also moved very close to the robot and leaned in, in order to be face to face with it. They wanted to remain in front of the screen. When the robot tilted the screen, nearly everyone tilted their heads as well, mirroring the robot's movements. Also, some moved around along with the robot and copied its movements.

### Reaction to non-responsiveness

People tended to turn to the experimenter when they were unsure of how to interact with the robot or when they suspected that it was non-responsive to their actions. Some lost interest quicker than others, and it was apparent when they gave up on the interaction. Their attention turned from the face to investigating the surroundings and the rest of the robot. This usually happened around 2 minutes in.

### Disconnect between face and arm

People experienced a disconnect between the arm movements and the projected facial animations. It seemed that the eyes correlation to the movement of the robot is very important to people. Without this, and with the eyes wandering around, it is hard to get a connection between the human. Also, the animated behaviour of the face combined with the movements seemed strange to people as well.

> 05:13 P6: My only real thing is that it's a strange disconnect between a rather apathetic looking person and what that appears to be a very curious robot. It's a bit of a strange, you know...

The head animation is moving on another pre-programmed loop, and its focal points and head-turns in relation to the arm movements sometimes goes against what seems natural to the participant.

### Connection between human and AH

As we analysed in the video data, the participants really wanted to keep focus on the face and have eye contact with the robot, but found it difficult due to the way the animations were playing.

> 01:15 P6: And he's never looking – ah well he doesn't appear to be ever looking straight forward. Like even now he's – There! Looking straight forward. But then, just before that, even with his nose, right, and he's facing you, he's down here. Like avoiding your eyes( ...). [about the gaze of the AH] (...) for a single person it means that he's not interacting with you, but everything around you and then randomly also you.

Like it is the case with humans, this participant's mental model of the AH was, that the eyes determines what object is of interest and the object the robot wants to interact with. As default, humans' attention is directed where the fovea is. It takes additional mental effort to focus ones attention in the periphery of focal vision, (Schwartz and Krantz, 2015, pp. 231-235). The face on the AH just seemed disinterested if the eyes appeared to avoid the participant. This would imply that the AH should have a strong correlation between its eye movements and the actual robotic arm movement. E.g. new person walks in from the right, the head is still, eyes saccade to the right, robot starts to move while the eyes adjust their gaze to keep the new person in focus. Otherwise, the AH should strive to maintain an eye position that is perceived as eye contact with the interlocutor, when it is interacting with an individual.

> 03:26 P5: Uh.. I think I tried to get his gaze? Like to catch his gaze . Sometimes it did seem that he was looking at me and other times it didn't. Yeah, I couldn't work out whether it was moving on a cycle, on a loop or whether it was actually interacting with me at one point just because of the way it moves. I was like "Oh, it's actually interacting with me" But I don't - after seeing it for some time I realise that it's on a loop. But even when I came up I still felt like at some points like it was seeing me or interacting at some points.

This quote is very interesting in the way the person describes that they realise the AH is on a loop but still got the sense that it was actually interacting with them. Again, it stresses the power that the eyes have in the interaction. The eyes should be synchronised with the robot arm movements and synchronised with the identified things of interest in the environment in order to accommodate the mental models of the participants which have been derived from real world social interactions with other people.

**Lack of interaction**

We believe that every participant figured out sooner or later that there was no real interaction, which was unsurprising. A lot commented that it was on a loop or a pattern either during their interaction or after in the exit interview. Understandably, the participants became unsure of the interaction, when they received no feedback, and some turned to the experimenter. Many greeted the robot verbally, and expected the robot to speak when they approached the face and be able to understand verbal commands.

> 03:18 P2: Just because of the combination of its physical movement and its movement inside, I see- and it's expressions, I see a huge permutation of available expressions. I just can't correlate them with my own interaction with it.

This participant describes well the overall conclusion from many of the individuals who participated.

### Understanding AH

As mentioned, the robot was positioned at a student event. The event was a chance for engineering students and post grads to show their work to representatives within the industry. This meant that many of the participants had interest in technological fields and were interested in understanding how the robot worked. After trying to elicit a response from the robot, most just sought to understand what would trigger the robot's movements. Some participants were very interested in the engineering side of the robot such as type of sensors and which vision condition we have applied in the system.

### Impression of AH

There were a lot of impressions expressed by the participants. Initially, the robot was, by some, compared to IBM's AI-powered companion for space stations, because of the way the face on the AH moves with the arm. Also, one commented that it moves just like Jarvis, a fictional AI from Marvel's Iron Man. At one glance, that was a lot of projected intelligence onto the robot and might show how people's expectations to robots and AI can be exaggerated when we combine them with human traits such as a face and dynamic movement. It was quite interesting that a robot arm moving in a repetitive pattern could initially elicit such connotations by the participants. Most addressed the AH as human ("he looks.." etc.) but one specifically mentioned, that the arm was more zoomorphic than anthropomorphic which they thought was weird when there was a human face attached.

> 01:58 ANDREAS: Okay... There's sort of a disconnect... between it's a face and then on an arm?
>
> 02:05 P6: Yeah well, it's a face – yeah. It's a face on an arm, not a face on a body.
>
> 02:09 ANDREAS: What would you prefer?
>
> 02:12 P6: That's a very good question.

Interestingly, this person, who commented on the robot being more zoomorphic because of the arm could not decide if they rather wanted a more human like body.

The participants generally believed that the AH seemed curious in the way it moved and some claimed it evoked curiosity in them to try and figure out what it was doing. It also seems that AH initially affords engagement, before they realise it is on a repetitive loop. AH was very captivating to some participants and appeared to have a significant presence even across the room.

One participant also commented on the lack of facial animations and how it was a bit disconcerting for them when the face did not speak or smile, but just came in closer:

> 01:13 P5: Uhm.. around his mouth, I think, like a lot of... you know. His eyes look really animated and then his mouth is very still. So.. yeah it's a bit – I think that's what makes it creepy actually. It's a little disconcerting. Because most of the time, peoples eyes would follow with a smile or a.. – something happens with the mouth as well.

If the AH should create the connection between the human and itself, as previously mentioned, these animations should also be considered. The complete lack of animation around the eyes and mouth was not ideal, and created discomfort for this participant. The AH was perceived as being in the Uncanny Valley as described by Mori, MacDorman, and Kageki (2012). We find that additional facial animations might mitigate this.

### Positive

A lot of participants were positive towards the robot in the end despite the fact that it was just running on a loop and there had been no cause effect interaction.

> 04:15 P1: This is awesome, man I love this sort of stuff, yeah.

> 00:37 P5: (...) [About the robot] It's really cool like, I loved it as soon as I walked into the room. It's very captivating. It's almost mesmerising, I think.

It is reasonable to assume that most participants were fairly positive towards robots in general to begin with, given the setting the study was conducted. One even specifically expressed so.

### Robo-ethics

This theme was created based on opinions towards robots in general that were expressed during the interaction. Here it seemed that participants were aware of the importance of ethics within AI and robot behaviour. Science fiction author, Isaac Asimov's three laws on robotics as described by R. Clarke (1993) came up when asked if there were places robots should not be. Also, it seemed that some were wary about how anthropomorphous they would like robots to become. Some even expressed that they did not want to personify the robot.

> 02:17 P1: I'm trying to work out what it is doing. And I'm trying to keep it as it is, instead of [ ] personified. Which is good, this is what I reckon [is] the thinking behind it from a high level.

The last sentence implies that the participant is glad that some are challenging these these ethical issues and starting a discussion about it. It could show that the AH would be able to elicit thoughts about AI technology and the ethical responsibility tied to it.

## 7.4 Sub-conclusion

### Quantitative data:

The calculated $\alpha$ values indicates low internal consistency therefore no means were calculated for the concepts, instead the mean for each items was calculated and analysed. From looking at the means of the items, tendencies were found the participants perceived the AH to move more elegantly than the overall perception of anthropomorphism. As expected from the predetermined movement, the participants rated the robot more apathetic than responsive. It was found that the participants seemed to like the robot and thought it had some intelligence, but not much. The participants felt safe around the robot.

### Qualitative data

From the analysis for the qualitative data ten themes where found. Three themes where found from the video analysis which is: sensing, placement and reaction to non-responsiveness. Seven themes was found from the interview analysis, where the themes are: Disconnect between face and arm, connection between human and AH, lack of interaction, understanding AH, impression of AH, positive and robo-ethics.

We found that people wanted to greet the robot verbally and expected the robot to be able to respond to questions. The participants wanted to stay in front of the monitor and the virtual head and the eyes was found important to the interaction. The participants' mental models were that the attention of the robot was focused on where the Articulated Head's eyes pointed. The participants seemed to experience a disconnect between the movements of the arm and virtual animations. The eyes should therefore be synchronised with the robot arm movements and synchronised with identified things of interest in the environment in order to accommodate the mental models of the participants. If the participant is the point of interest then the AH should maintaining eye contact with the interlocutor. Otherwise, the Articulated Head will appear disinterested and apathetic towards the participant.

The lack of facial expressions around the eyes and mouth combined with silence contributed to some placing the Articulated Head in the Uncanny Valley, where they felt a little disconcerted by the robot. It is possible that adding a bit more expression could mitigate this discomfort. Also, it appears that the Articulated Head is perceived as having a presence in the room despite not being reactive. We observed that people trusted the robot despite coming close to them, which indicates that they felt safe around the robot.

Some expressed it was hard to place whether it was zoomorphic or anthropomorphic and some thought it was either of the two. This shows promise when thinking about the context of the *Born or Built?* exhibition and how the AH seems able to spark debate. We noticed that people tended to turn to the experimenter, when they were unsure about something this could be worth having in mind for future studies if a natural interaction with the robot is wanted without focus on the experimenters.

# 8 Main Study in the Lab with Focus Group

A main study was conducted in the lab to be able to compare the results to those found in the wild and thereby see if the results from a lab study could transfer reliably to a real world setting. In this study we had the opportunity to have a group of ergonomists as participants which we utilised by conducting an focus group interview with them to explore if they might have any knowledge based on their profession relevant to our study of human robot interaction.

## 8.1 Human Observation Lab as Setting

For the lab study, we utilised a newly built human observation lab which is a very controlled environment already fitted with multiple cameras and microphones. For this part, we chose to invite a group of ergonomists from the Human Factors and Ergonomics Society of Australia (`https://www.ergonomics.org.au/-Accessed2019-05-07`).

This was conducted with only one condition as we did at the UC campus event. They were presented with the predetermined movement condition and then asked to individually rate their impression of the robot. After their interaction with the robot, we stayed in the observation lab to begin the focus group session where they could observe the robot while discussing it. See Figure 8.1 and Figure 8.2 for a schematic of the lab setup and photos of the lab.

Additional to the questions presented in the research design, the focus group was also asked a series of questions regarding studying HRI and how they might provide us knowledge to improve our study. See section 6.3 for the questions asked.

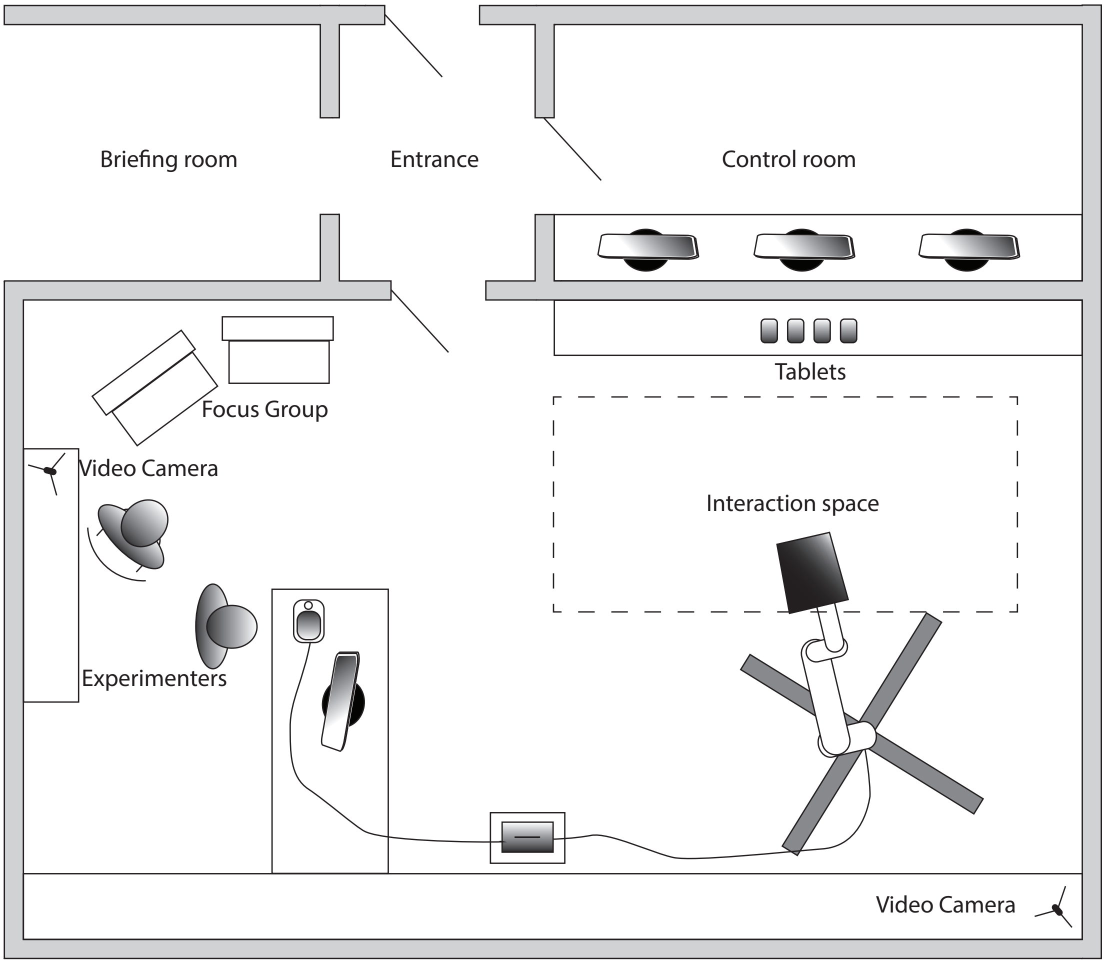


***Figure 8.1.*** A schematic of the observation lab we used for the study.

***Figure 8.2.*** Pictures from the setup in lab. Left is the view of the robot from the entrance. Right is where the focus group was conducted afterwards.

## 8.2 Findings from Quantitative Data

Three participants participated in the study in the lab and all answered the Godspeed questionnaires right after they had interacted with the robot this gave us 3 ratings on 24 items that can be divided into five concepts; Anthropomorphism, Animacy, Likeability, Perceived Intelligence and Perceived Safety. Because our sample size is so small (N=3) we decided not to calculate the mean for the concepts, but calculated the mean for each item instead.

## Anthropomorphism

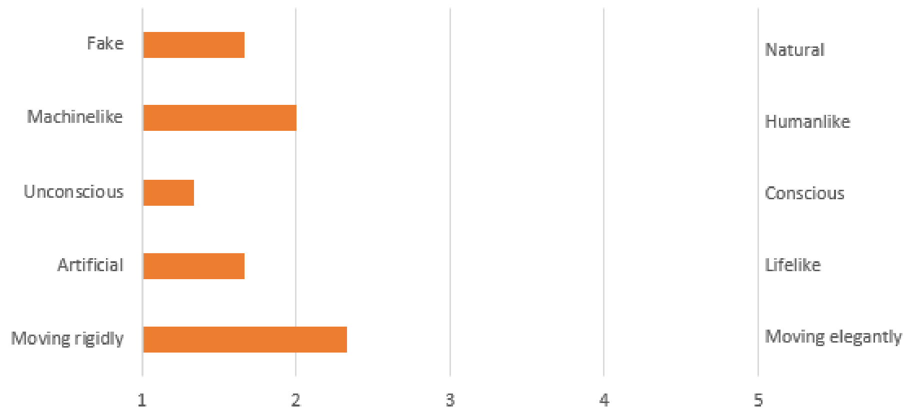


***Figure 8.3.*** Average rating on each item regarding Anthropomorphism at the study conducted in the lab.

The mean for all five items regarding anthropomorphism is quite low. The only mean that is over 2 is for the item Moving rigidly/Moving elegant but only just above 2, which means that the participants found it to move more rigidly than elegantly. The overall impression when looking at the means on Figure 8.3 is that the participants found the AH to have a very small degree of anthropomorphism. This could come down to them being professionals within human factors and knows the human body well and how it behaves. The ratings also show that they really felt it was unconscious which could be attributed to them interacting for a longer time with the robot and that the robot did not respond to any of their interaction attempts.

## Animacy

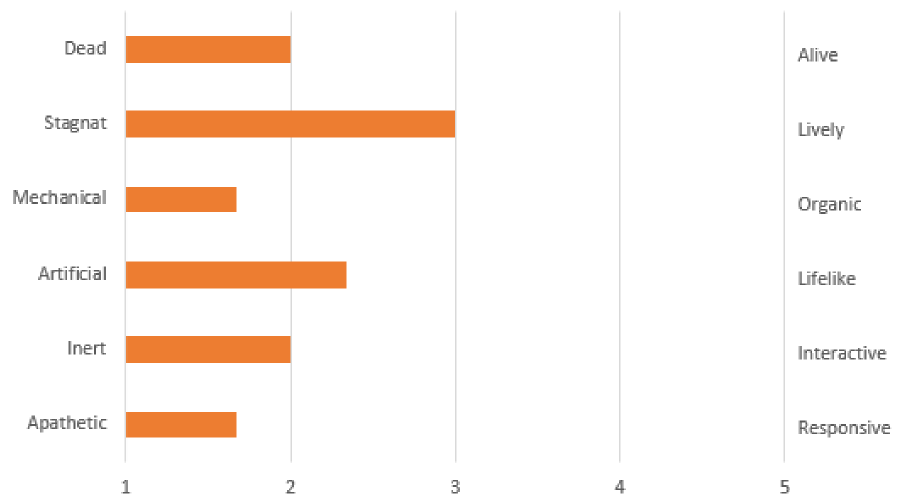


***Figure 8.4.*** Average rating on each item regarding Animacy at the study conducted in the lab.

Based on the means presented on Figure 8.4 it indicates that the participants found the AH to have a low degree of animacy. The participants seems to have found the AH to be very mechanical and apathetic. The mean of Stagnat/Lively indicates that the participants neither found the AH to be stagnat nor lively. The reasoning for this could be that the robot did move all the time, but it moved in the same pattern and the participants realised that during their interaction with it.

### Likeability

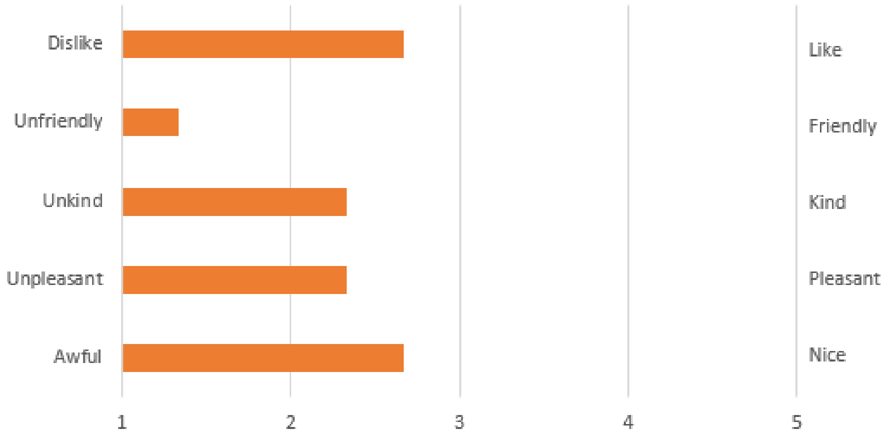


***Figure 8.5.*** Average rating on each item regarding Likeability at the study conducted in the lab.

One of the items regarding the likeability of the robot is a bit lower than the other four when looking at Figure 8.5. The item is the one about the rating of Unfriendly/Friendly where the mean is almost at the endpoint Unfriendly. It is interesting that they tend to perceive it as unfriendly when all it did was move on a repetitive pattern. Perhaps it was considered rude when it was "ignoring" their attempts to elicit a response.

### Perceived Intelligence

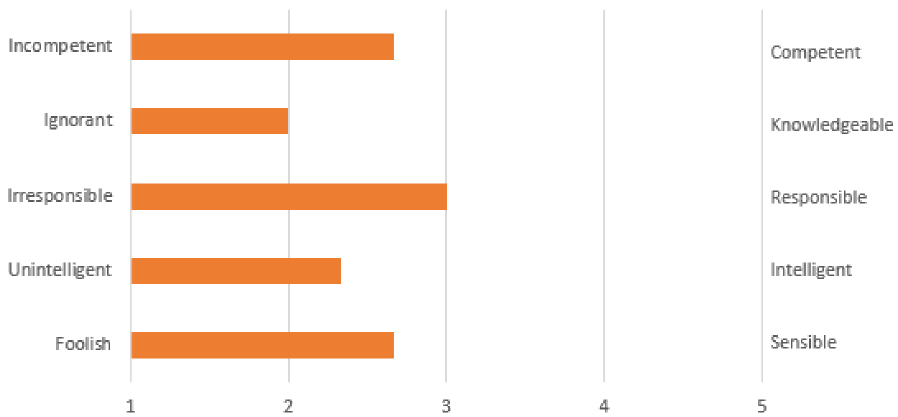


***Figure 8.6.*** Average rating on each item regarding Perceived Intelligence at the study conducted in the lab.

The perception of the intelligence of the AH does not seem to be high when looking at the means presented on Figure 8.6. Despite not being perceived as very intelligent, they did not perceive it as being irresponsible either, nor did they find it to be responsible. This could indicate that the AH did not actively do anything to show if it was responsible or not. If the participants had interacted with the robot in a way that would have made it necessary for the researcher to use the emergency stop, this rating on Irresponsible/Responsible would likely have been lower and more similar to the overall perception of the robots intelligence.

### Perceived Safety

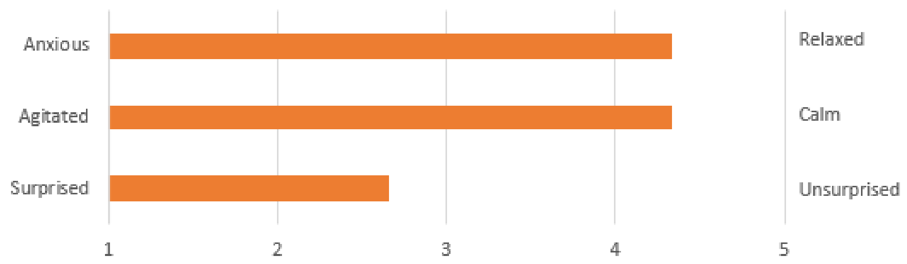


***Figure 8.7.*** Average rating on each item regarding Perceived Safety at the study conducted in the lab.

The means presented on Figure 8.7 show that the participants felt quite safe around the robot even though their ratings indicate they were surprised by it at the same time. This could be related to what expectation the participants might have had before taking part in the study. If they found the AH to different from their expectations, it could get them to feel surprised by it even though they still perceive the robot to be safe.

## 8.3 Findings from Qualitative Data

For our study in the lab, we recruited three professionals working within human factors from the Human Factors & Ergonomics Society of Australia (HFESA) (`https://www.ergonomics.org.au/`). They were briefed in a briefing room prior to entering the observation lab where the robot was positioned.
The transcription including codes of the audio data can be found in Appendix A.12 and the video codes can be found in Appendix A.13.

### The part of the interview being analysed

Due to time limitations we chose to only analyse a part of the interview to be able to do a full analysis on this part. First part of the interview is transcribed but not analysed using the thematic analysis method. The reasoning for not including the first part of the interview regarding the general questions about robots, is the lack of possibility to compare the findings with the study at the UC event, where only a few of the questions where asked. In the analysis the goal is to analyse the participants experience of and with the AH and the first part of the interview is only regarding robots in general and not the AH, which is a second reason for choosing not to include that part of the interview in the analysis. The last part of the interview regarding the questions design for the focus group was not analysed either, again the decision was made based on the lack of possibility to address our problem formulation by compare this findings to the findings from the study conducted in the wild.

### 8.3.1 Themes

We analysed the video data first and then the transcribed interview. From the video data we had 57 initial codes which were grouped into 12 focused codes and were finally categorised into 4 themes. See Figure 8.8 for the theme map and see Figure 8.9 for a rough overview of the coding process.

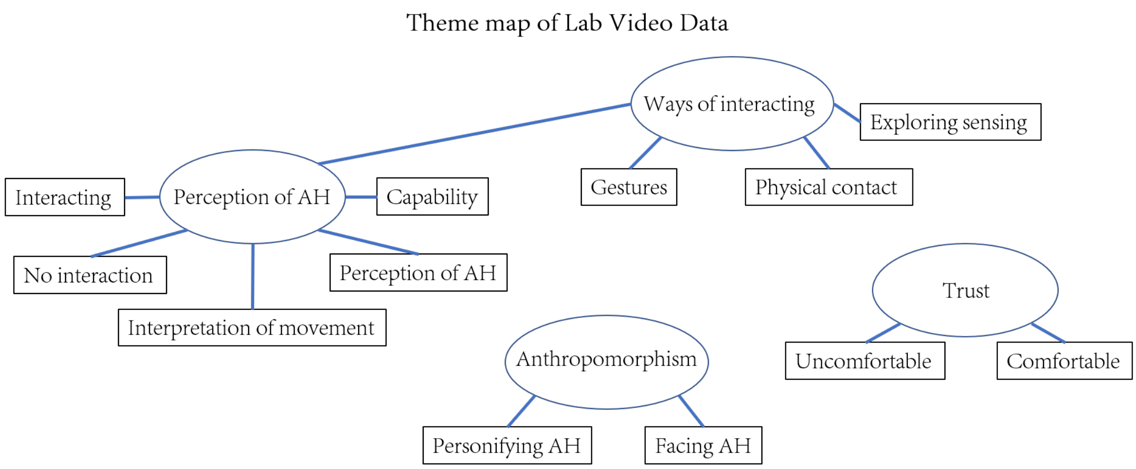


***Figure 8.8.*** Theme map from the thematic video analysis from the lab. The ellipses represent the major themes, and the rectangles the focused codes. The lines are drawn to show which themes and focused codes are connected in the data.

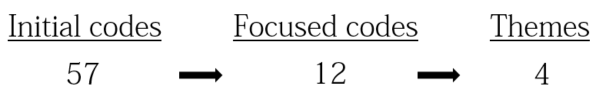


***Figure 8.9.*** Shows the procedural steps how we arrived to the 4 themes when coding the video data: 57 codes were grouped into 12 focused codes and created 4 themes.

When we analysed the interview data, we had 44 initial codes which were grouped into 8 focused codes and were finally categorised into 2 themes. See Figure 8.10 for the theme map and see Figure 8.11 for a rough overview of the coding process.

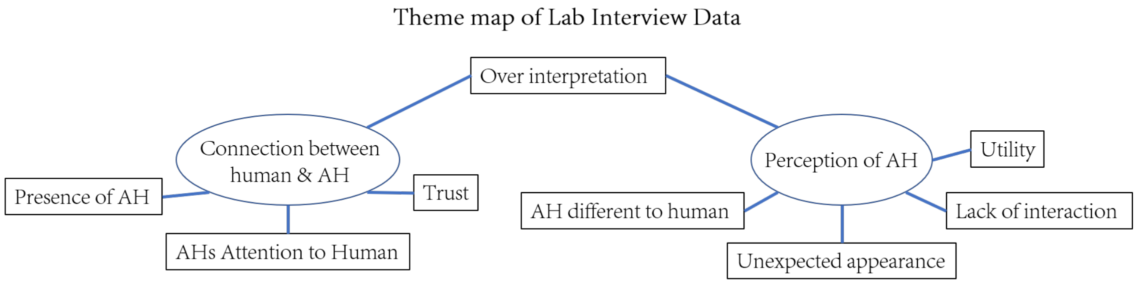


***Figure 8.10.*** Theme map from the focus group in lab based on their experience after interacting with the robot. The ellipses represent the major themes, and the rectangles the focused codes. The lines are drawn to show which themes and focused codes are connected in the data.

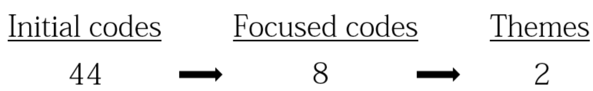


***Figure 8.11.*** Shows the procedural steps how we arrived to the 2 themes when coding the video data: 44 codes were grouped into 8 focused codes and created 2 themes.

### Perception of AH

This theme emerged from four focused codes: *Interpretation of movement, perception of AH, interacting*, and *no interaction*. The group all agreed that there was no interaction with AH before rating the robot. Yet, before they came to that conclusion, there were incidents where they thought it did react to their movements e.g. one stepped to the side, said "hello", and the robot moved in their direction, which the participant interpreted as a responsive movement. This happened initially but quickly the illusion collapsed and they saw it for what it was; just moving in a repetitive pattern. After having tried personal greetings, they started to ask questions as if it was a service robot, e.g. asking if it could show them the way to the cafeteria, which was an interesting shift from their initial approach of trying to get acquainted with the robot.

It was interesting to note how they interpreted the robot movements as being somewhat reactive initially. They also explained how the movements of the screen alone conveyed curiosity. When the screen tilt happened in combination with the animation tilting its head as well, AH was perceived as quizzical. This might imply that a sync or relationship between the virtual animation and the physical movement could create a more powerful experience for the interlocutor.

### Ways of interacting

The participants showed various interaction possibilities such as gestures, verbal communication and body position. They expected it to respond to commands, questions or greetings. One participant gestured for it to come closer once more and said "come on" like you would if you were calling on a pet. They were very close to the robot and even tested physical interaction with the screen e.g. lightly stroking the cheek of the animated face. This, however, was one of their last attempts to get the robot to react to their input. This implies that physical interaction was not their first choice of interaction, but they trust the robot well enough to be comfortable touching it after a few minutes.

### Trust

The participants showed signs of being nervous around the robot when it came too close in the beginning. They wanted it to come closer but not too close and would occasionally step back.

> VFront 10.00 P11: (...) My first reaction was to step backwards, but I don't feel I needed to step backwards..

But after a few minutes they were comfortable going really close to the robot, moving behind it and even touching it.

### Anthropomorphism

We saw a great tendency for the participants to want to be at the centre of the screen, facing it. Their mental model of how the AH worked was that the attention of the robot was parsed through the screen. This showed when a participant waved their hand in front of AH's animated eyes after a couple of interaction attempts as one would do to a seemingly unresponsive person. They also wanted to gauge the AH face's reactions to some of their interaction attempts. E.g. one participant touched the virtual face on the cheek and the robot immediately turned away, which prompted a response from the participant "Oh, he did not like that!" while trying to retain their view of the face to see its reaction.
They also personified the robot, expecting it to have a personal name. One expected it to conform to movements within human capability and therefore also prefers the proportions of AH closer to a human's as opposed to how it was presented. The participants showed signs of feeling a connection with the robot. It appears that the robot is perceived as having presence as it is able to disrupt their personal space:

> VLab 09.47 P11: "(...) Definitely an interpersonal thing going on here. I was thinking, 'it's okay, I can stand here, I know it's not a person', however I still feel an interpersonal distancing."

They also mirrored AH's movements e.g. when the screen tilted, they tilted their own heads.

It seems that adding a face on the robot notably elevates peoples expectations to the interaction and they draw on knowledge from real social interactions when trying to engage the robot.

### Connection between human and AH

This theme was created from three focused codes: *Presence of AH, AH's attention to human,* and *Trust*. It was apparent that they all perceived the AH to have some sort of presence in the room as mentioned in the Anthropomorphism theme.

> 31.25 P11: Yeah it does.. Even at this level it still has a presence.

They felt that AH is great at drawing attention in a room. They mentioned that this quality of presence could help comfort dementia patients as just any feeling of presence is greatly helpful to the patients. They also mentioned that the AH could make one feel observed.

They trusted the robot to not hurt them and perceived it as quite harmless and generally felt safe being around the robot. They noted that a male face inspires trust and the AH in itself could contribute to a sense of security. This could come down to the setting or to the fact that the robot had a human face and moved rather smoothly. Perhaps developers need to be careful about which robots receive a face, if that is creating a false sense of security, and the robot in fact is not completely harmless.

This connection the participants describe with the AH was also conditioned by the AH's attention to them. They felt inanimate when the AH practically ignored them and longed for just a simple sign of acknowledgement to their own presence. The participants did not think that AH made eye contact which, according to them, is very important in facial communication. They wanted to see more expression communicated through the face, and they noted that what is presented on the monitor greatly affects the overall perception of the robot. This, combined with the robot having presence, could be utilised to encourage creative thinking in a room when a specific mindset is needed, e.g. thinking about inclusive design by presenting different nationalities on the AH.

### Perception of AH

This theme consisted of four focused themes: *Unexpected appearance, AH different to Human, Utility,* and *Lack of Interaction.* The participants mentioned that they were surprised by the mechanical appearance and had expectations of a more anthropomorphic or zoomorphic robot:

> 24.26 P2: I was surprised of the form of it. [ ] I wasn't expecting a sort of trolley with a screen. At all. So it might be...
>
> 24.38 J: So what did you expect or did [ ] ?
>
> 24.40 P2: I guess more like the Japanese types. Little seals, white seals.

The AH also did not meet the quite low expectations for interaction that the participants had prior to seeing the robot. They would rather have extremely limited interaction than none, and they explained that, had there been more interactivity, they would immediately be more inclined to maintain engagement for longer, and reckoned that they would likely assign the robot more capabilities than were actually present. They only resorted to physically interaction after previous verbal and gesture attempts did not seem to work.

Touching the face of AH was not perceived as socially unacceptable as it would be the case with another human being that one has just met, all though it was only something that they attempted after depleting other ideas for communication such as speech.

## 8.4 Sub-conclusion

### Quantitative data

Because of the very small sample size at only 3 the means for each items was calculated instead of the mean of the concepts. Looking at the means we fund that the participant had found the robot to have a very small degree of anthropomorphism and low degree of animacy. The participants neither found the AH to be stagnat nor lively. The friendliness of the robot is perceived to be lower than the overall likeability. The participants fount the robot to be very little intelligent but they did not perceives it as being irresponsible either nor did they found it to be responsible. The participants felt safe around the robot even though they seem to have been surprised by it at the same time.

### Qualitative data

From the analysis of the qualitative data six themes was elicited. From the thematic analysis of the video data we found four themes: Perception of AH, ways of interacting, anthropomorphism and trust. From the thematic analysis of the interview data we found two themes: Connection between human and AH and perception of AH.

We found that the group expected the robot to respond to verbal greeting and to their movements which indicates that people are projecting capabilities unto the robot that was not there. It seems that adding a face on the robot notably elevates peoples expectations to the interaction and they draw on knowledge from real social interactions when trying to engage the robot. The participants' mental model of the Articulated Head's was that it perceived the environment through the eyes of the animated head making gestures right in front of the virtual eyes. They wanted to stay in front of the monitor and wanted to have eye contact with Articulated Head. They felt inanimate and ignored by the robot when it did not acknowledge them. They wanted more expression to be communicated through the face and underlined the importance of how the overall robot is perceived differently depending on what is presented on the monitor. It was found that a synchronicity between virtual agent and physical movement could create more powerful and meaningful experiences with the interlocutor. The participants perceived the Articulated Head as having presence in the room. They felt comfortable enough to get close to the robot and even walk around it.

Coming into the lab, the participants had preconceived expectations to the capabilities of the robot and also the appearance of the robot. They were surprised by the mechanical look and expected a more zoomorphic or anthropomorphic robot mentioning japanese-style robots.

# Comparing Findings from Different Settings 9

To address the part of our problem formulation regarding *To what extent do the results from study in the laboratory transfer reliably to real world settings?* we compare the findings from the different settings in this chapter.

## 9.1 Findings from Quantitative Data

In the individual analysis of quantitative data from each study we only looked at the means of the individual items for each of the five concepts. This comparison will be on the same data and graphs merged to one to visualise the possible differences and similarities.

### Anthropomorphism

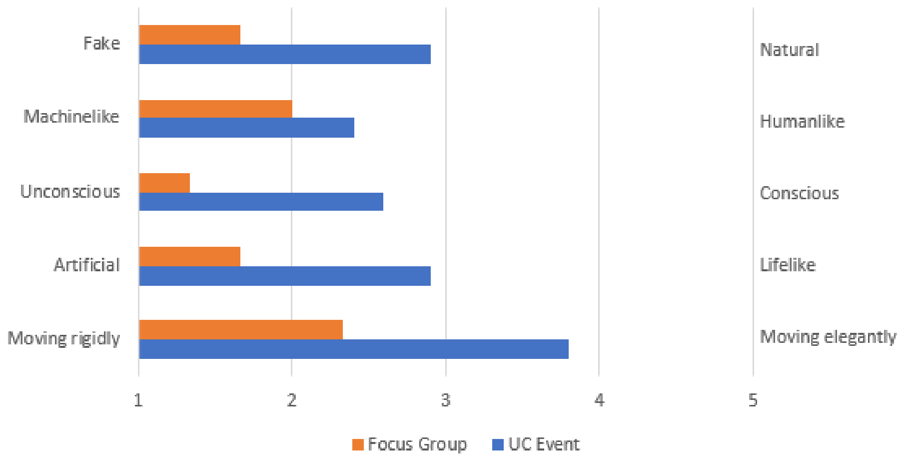


***Figure 9.1.*** Average rating on each item regarding Anthropomorphism from both the in the wild study at the UC event and the study in the lab with the focus group.

The overall tendency we see when looking at means presented on Figure 9.1 is that the participants at the study in the lab found the robot to be less anthropomorphic than the participants at the UC event. The item with the least difference between the means is Machinelike/Humanlike, this item is also the one with the lowest mean for the study at the UC event, which could explain why the different is smallest for this item.

### Animacy

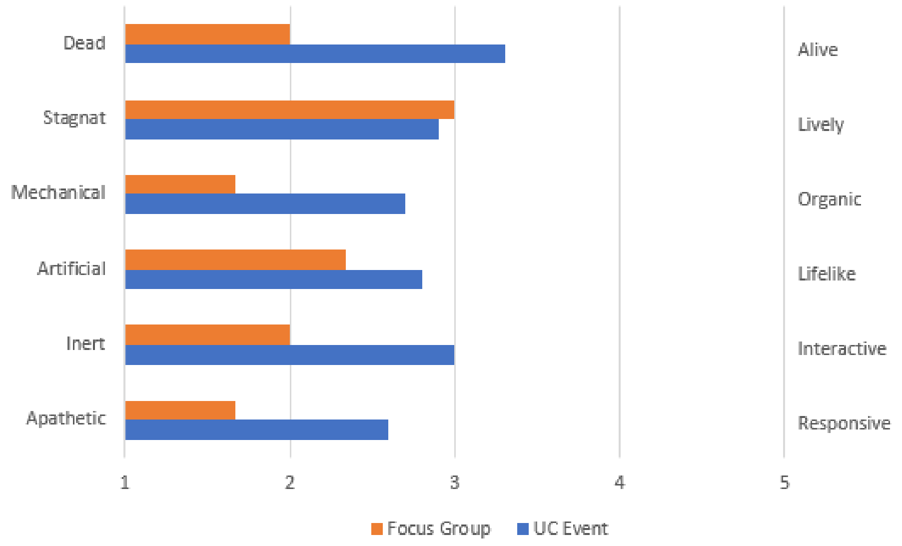


*Figure 9.2.* Average rating on each item regarding Animacy from both the in the wild study at the UC event and the study in the lab with the focus group.

The means for the items regarding animacy presented on Figure 9.2 indicates that the animacy of the AH is rated higher in the study at the UC event compared to the study conducted in the lab.

The mean of Stagnat/Lively is for both studies close to the middle which indicates that the participants neither found the AH to be stagnat nor lively. The reasoning for this item standing out could be that the robot moved around all the time, but it moved in the same pattern and the participants realised that during the interaction with it.

### Likeability

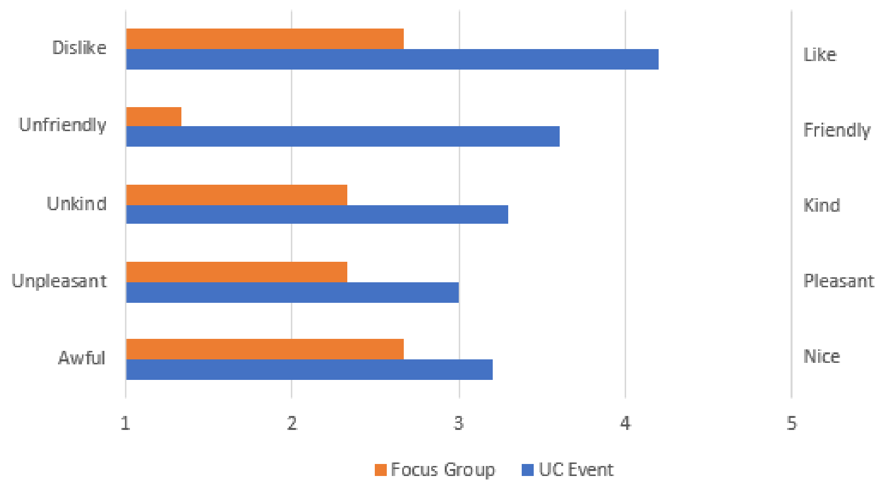


*Figure 9.3.* Average rating on each item regarding Likeability from both the in the wild study at the UC event and the study in the lab with the focus group.

The means showed on Figure 9.3 indicates that the participants at the UC event rated the robot higher on the concept likeability than the participants at the study in lab. Especially the mean of the item unfriendly/friendly is very different between the two studies. Participants in the lab seems to have found the robot unfriendly whereas the participants at the UC event found the robot to be friendly.

### Perceived Intelligence

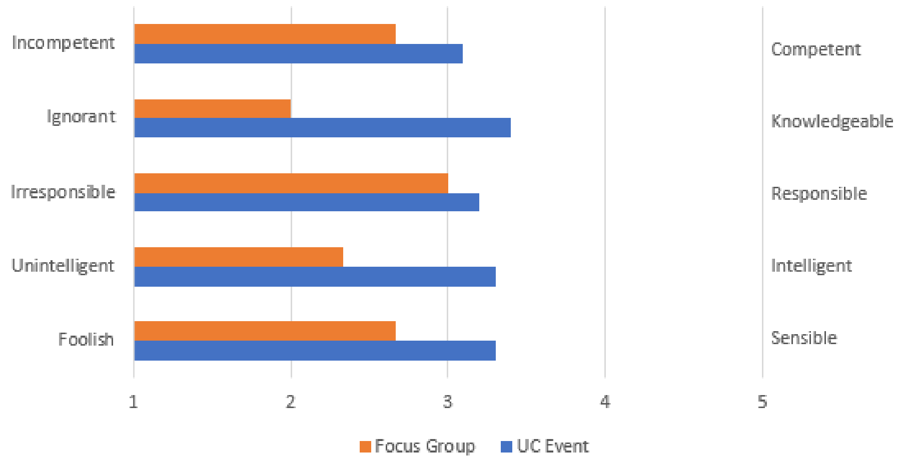


***Figure 9.4.*** Average rating on each item regarding Perceived Intelligence from both the in the wild study at the UC event and the study in the lab with the focus group.

For all five items regarding the perceived intelligence the mean from the UC event is higher than the mean from the lab as showed on Figure 9.4. For the item irresponsible/responsible the difference between the means is very small and both close to the middle. This indicates that it does not seem as the participants found the AH to be irresponsible nor did they find it to be responsible. This could because the AH did not actively do anything to show if it was responsible or not. If the participants had interacted with it in a way that would have required the researcher to use the emergency stop, this rating on Irresponsible/Responsible would likely have been lower.

### Perceived Safety

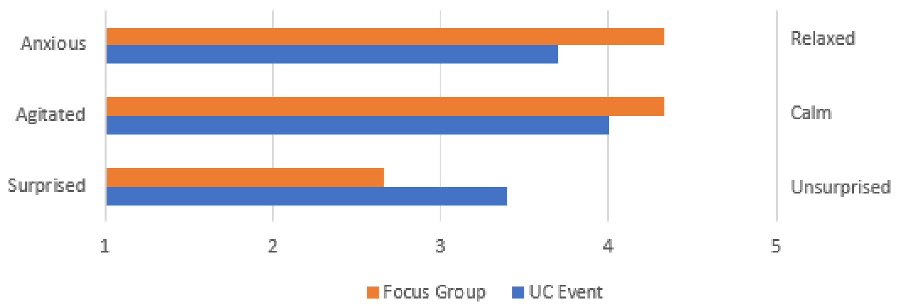


***Figure 9.5.*** Average rating on each item regarding Perceived Safety from both the in the wild study at the UC event and the study in the lab with the focus group.

It seems from Figure 9.5 that the participants in both studies felt safe interacting with the robot and the participants at the lab might have felt a bit safer then the participants at the UC event. This could come down to the different setting, as the UC event was very vibrant with people and the noisy environment whereas the lab was a quiet, controlled setting. The means could indicate that the participants in the lab was more surprised be the robot than the participants at the UC event. This could have been influenced by the fact that the participants at UC event could see the robot during the event and when they interacted with it, they might already have observed it. For the participants at the lab there was no time before hand to observe the robot, they interacted with it right from the moment they entered the room it was placed in.

## 9.2 Findings from Qualitative Data

We look into which similarities and differences we found between the two settings and between the results obtained from the participants. In total, we found 16 themes after conducting our thematic analysis on the video and interview data. We saw a lot of similar themes emerging between the two studies in different settings and in the perception of the robot. We have tried to summarise these findings in the following.

### 9.2.1 Findings from thematic analysis

In both settings, we found that people naturally wanted to greet the robot verbally with a "hello" and expected it to respond to questions as well. The eyes held a lot of power over the interaction and most sought eye contact with the robot, but most of the time did not experience any. They wanted to stay in front of the monitor and the virtual head, sometimes also to gauge the Articulated Head's facial reactions to certain movements or commands.

Initially they thought that the robot reacted to their movements indicating that people are projecting a lot of capabilities unto the robot that might not be there, and over interpreting movements or gazes. It seems that adding a face on the robot notably elevates peoples expectations to the interaction and they draw on knowledge from real social interactions when trying to engage the robot.

People's mental models were that the attention of the robot was focused on where the Articulated Head's eyes pointed, some making gestures directly in front of the virtual eyes. It confused the participants and seemed unnatural when the movements of the arm and virtual animations did not correlate. The eyes should therefore be synchronised with the robot arm movements and synchronised with identified things of interest in the environment in order to accommodate the mental models of the participants which have been derived from real world social interactions with other people. This includes maintaining eye contact with the interlocutor. Otherwise, the Articulated Head will appear disinterested, apathetic, or causing the participant to feel ignored.

The lack of facial expressions around the eyes and mouth were noted in both settings. It appears that this lack of expression combined with silence also contributed to some placing the Articulated Head in the Uncanny Valley, where they felt a little disconcerted by the robot. It is possible that adding a bit more expression could mitigate this discomfort. Also, it appears that the Articulated Head was perceived as having a presence in a room despite not being reactive. At the UC Event, one commented that they felt there was an interaction going on even though they realised it was on a loop. In the lab it was described as if there was an interpersonal thing going on when the robot approached the participants and got close. Here too, they perceived the Articulated Head as having presence and saw that as an opportunity to comfort dementia patients.

In both settings, we saw the participants mirror the movement of the robot. Especially when the screen tilted, prompting the participants to tilt their head as well. It showed that there at times was some connection between the participants and the robot. This also ties back to the robot being perceived as having presence.

We observed that people trusted the robot despite coming close to them, which indicates that they felt safe around the robot. In the lab, they appeared nervous at first but after a short while were comfortable walking around it and getting real close to it, even touching it, which we did not observe in the wild.

Some expressed it was hard to place whether it was zoomorphic or anthropomorphic and some thought it was either of the two. This shows promise when thinking about the context of the *Born or Built?* exhibition and how the AH seems able to spark debate. We noticed that people tended to turn to the experimenter, when they were unsure about something. This could be worth having in mind for future studies if a natural interaction with the robot is wanted without focus on the experimenters.

### 9.2.2 Setting

Coming into the lab, the participants had preconceived expectations to the capabilities of the robot and also the appearance of the robot. They were surprised by the mechanical look and expected a more zoomorphic or anthropomorphic robot mentioning japanese-style robots. That did not seem the case with the study at the UC Event where the attendees had no idea that a robot was going to be there. How a specific setting can contribute to certain expectations, is worth keeping in mind when conducting future studies.

After we had collected the video data from the UC Event we wanted to ensure that we did not publicise images of people without their consent. Data from in the wild studies therefore can take a lot of extra work, because people move dynamically around the room. This means that people who have not agreed to participate or to be filmed will be captured on the camera. A solution to this is to install the camera at an angle so that only the participants and their interaction is in frame, but that might not always be a possibility. Therefore one has to be prepared to blur the faces of the bystanders due to ethical concerns. Depending on where the study takes place, one also has to expect a very noisy environment when collecting data in the wild. This leads to considerations of audio recording devices and how directional their microphone are. If the microphone is set up as omni-directional, the audio recording is not narrowly focused, and it can be very hard to discern what is being said by the participants unless one is very close, which is not always a possibility.

These considerations regarding video, along with transcribing the data collected in a noisy environment, is very time consuming and needs to be taken into account when conducting in the wild studies.

## 9.3 Sub-conclusion

### Quantitative data

The overall impression from comparing the means of the ratings from the two studies is that the participants at the study in the wild at the UC event rated the AH higher on the four concepts: Anthropomorphism, Animacy, Likeability and Perceived Intelligence. The participants from the two studies seems to have rated the AH equally safe where the participants in lab might have been less surprised by the robot than at UC event, and seemed more relaxed and calm. The item with the biggest difference between the means was unfriendly/friendly where the participants in lab seems to have found the robot unfriendly whereas the participants at the UC event found the robot to be friendly.

### Qualitative data

The Articulated Head should have a correlation between the facial animations and the physical movement of the robot in order to create more powerful experiences. In both settings the participant's focused a lot on the Articulated Head's eyes and tried to gauge where it had its attention. The group in the laboratory setting appeared to have preconceived expectations which was not observed with the study at the UC Event. The setting might influence which expectations participants have prior to participating which could influence their actual experience.

# Discussion 10

## 10.1 Research design

The research design for the main studies was created and adjusted through out the project until the studies were conducted. Several elements of the final research design is worth to discuss in order to reflect upon the pros and cons of the decisions made when choosing the research design.

### Godspeed Questionnaires

In both the grounding study in the lab and in both main studies the Godspeed questionnaires was used to measure the participants perception of the robot on five different concepts. These questionnaires by Bartneck et al. (2009) are a commonly used as a rating system in studies about HRI but it is not a standard and there might therefore be some important considerations to make regarding the use and analysis of it.

When using the five Godspeed questionnaire we did not adjust for order effect when asking the subjects to rate their interaction using the Godspeed questionnaire. This means that items and concepts being rated was presented in the same order each time and there might be an effect on our results of this specific order.

For the analysis of the ratings we calculated means from the scale items derived from a 5-point likert scale, which according to Bartneck et al. (2009) is the calculation to make, to get a score on each concept. It could be argued, that the ratings simply does not have a high enough resolution for it to be treated as numerical means in the data analysis. In other words, it is ordinal data and not continuous. In a future study, it would be interesting to see whether or not a Visual Analogue Scale (VAS) would actually be a better way to present the scale items. It is often described as a 101-point scale, but can have an even higher resolution. According to Lewis and Erdinç (2017), though, it does not make much difference to the results in the end whether the scale is 7-point, 11-point or 101-point. But how one presents the data perhaps should be reconsidered, when using low resolution scales such as a 5-point or 7-point scale.

It could also be worth looking into the endpoints of the scales if they ought to have a section of the scale beyond the final endpoint as this would give the participant the possibility to surpass ratings given earlier that they thought was the maximum of this item they would experience - this is specially important to discuss for a within-subjects design where each participant rates on the same items several times like they did in our grounding study. In our main studies, the participants only rated one time and were presented with all the items on the same page and had the possibility to change their ratings while rating the rest of the items. This would make it less important to have a section of the scale beyond the final endpoint.

### Movement of the robot

The movement of the robot can have a great influence on the perception of the robot which make it important to discuss the design of the movements of the robot in our studies. Hoffman and Ju (2012) stresses the importance of being aware of the design and effects of accurate expressive motion.

The movement of the robot in the grounding study were conceived with a cardboard as monitor and with a printed face on top and was also presented to the participants this way. By conceiving the movements with the face on the robot it can be argued that a natural coherence between the two was made as the face was taken into the design process. It is important to be aware of the importance of creating this connection between the face and body of the robot. Previously in section 2.4 the FACE by Lazzeri et al. (2018) was presented and their conclusions seem relevant in this discussion. Lazzeri et al. (2018) concludes that body and mind goes together when building an intelligent embodied agent, seen from a biological and robotic perspective. Therefore it is important to include both elements in the design of the robot, even in our case where the robot is moving in a pre-programmed loop of movements.

When designing the movements for the main studies it could be seen as a second iteration of the design of one of the movements from the grounding study. In our grounding study in lab we explored how the participants experienced the movements from two different positions of the base. It was valuable for the design of the movements for the main studies to include experience from the participants especially in our case with the pre-programmed loop of movements to be able to have some interaction between the participants and the robot. The experience with testing the movements can also be used to improve the movement with THAMBS.

### Data analysis

Due to a lot of influencing factors we ended up with quite a limited amount of test subjects. Ideally, it would have been possible to collect real world data from visitors attending the *Born or Built?* exhibition. In less than 4 months, they have had over 180.000 visitors come through their exhibition space, meaning no shortage of research participants. It should be possible to match the amount and type of participants in a lab setup afterwards in an attempt to keep the conditions between the two setting as similar as possible.

The way we applied the Thematic Analysis could also be a limitation of our research. We only had the two authors to conduct the coding and organise them into focused codes that eventually turned into our themes. One could argue that it is preferable to have a larger group when conducting this analysis in order to not have a too biased outcome from the researchers and in order to better see connections across the data. A disadvantage of bringing in outsiders might be that they then are not familiar with the overall research question that the researchers are trying to investigate. Also, they most likely were not present at the time of data collection and are not very familiarised with the data which could cause them to misinterpret the meaning of statements in the transcript.

The use of Thematic analysis in analysing video data would probably be reconsidered next time around. The themes from the interview data and the themes from the video data that we ended up with could seem to be too separated from each other despite being derived from the same study and participants. Perhaps it is possible to synthesise the theme maps even more by connecting themes across the video theme maps and interview theme maps and see if it is possible to present clearer overarching themes. It might also be beneficial to return to the codes and look into re-coding some in order to really investigate the qualitative data recursively. In the scope of our project, it is questionable how much more valuable findings would have been brought to light by pursuing a more thorough thematic analysis compared to what we already found and presented in this report.

### Mixed-Method Approach

We used the Godspeed questionnaire to get numeric data in order to analyse the participant's experience statistically. We failed to secure enough participants to ensure validity of the data but we also used a thematic analysis of interviews and video data. This mixed-methods approach worked great despite the small sample size. We were not able to do the statistical analysis but we could show tendencies when we combined the qualitative data with the quantitative, which helped support each other and aided the overall reliability of the results. If we did not have the qualitative data analysis we could not have said much based only from the Godspeed ratings given the sample size.

## 10.2 Differences between participants

There are some quite notable differences between our participants in the two main studies and how they were recruited. In the lab study, we chose to recruit professionals from the Human Factors and Ergonomics Society of Australia who knew quite a lot about how the human body and its interaction with machines. They agreed to participate in our study a couple of weeks prior to conducting it. They were only told that they were going to be interacting with a robot and that a focus interview would be conducted. Despite not knowing exactly what was going to happen, they still had time to prepare themselves for the study and mentioned themselves that they had expectations prior to the interaction. These expectations might have affected their ratings on the Godspeed in that the robot did not meet them. They expected a completely different experience e.g. a responsive japanese styled robot.

The people recruited at the UC Event did not know that there was going to be a robot prior to coming to the event and were recruited on site where they themselves had chosen to be. Most who attended did, however, work within STEM fields (Science, Technology, Engineering, and Mathematics) which could have biased their affection towards the robot, which might have showed in their Godspeed ratings which were generally rated higher compared to the focus group in lab. Whether or not this was purely due to differences in participants, a change in setting, or both, we can not really say. However, we noted that the participants in lab tried to engage with the robot for a lot longer time than the participants at the UC Event. This extra time spent with the robot could have influenced the ratings as well, as it might suggest that people are very positive initially but the longer time spent in front of the unresponsive robot, the more their expectations and excitement evaporates.

### 10.2.1 Expectations of the participants

The participants in the to main studies might have had different expectations to what kind of study it was they were going to participate in. In the qualitative data we found that the participants in the lab did not think the robot lived up to their expectations. In the quantitative data we found that they for the four concepts regarding their perception of the robot rated it lower than the participants did in the study at the UC event.

The difference in expectations between the participants in the two studies might be due to the nature of the recruitment of the participants. In the lab study the participants were recruited two weeks prior to the study, therefore they knew in advance that they where going to participate in a human robot interaction study and had time to think about how that might be. The participants in the in the wild study was recruited on sight at the event, they did not know that the study was conducted before they attended the event and therefore did not have time to build up expectation the same way the participants in the lab study had. This discussion stresses the importance of being aware of how the participants might be effected prior to their participation in the study and how this might influence the findings.

For the recruitment of participants in our two studies we found it unlikely to use the same method. The participants in our study in the wild was there for another purpose; to attend a student event. In the lab, their only purpose for being there was to participate in this specific study, and it would be hard for them to act naturally. A way to address this, could be to disguise the study within another study. During the project, we discussed this slight deception by inviting people into the lab to participate in one HRI study that had two conditions. While the second condition was being prepared we could ask them to wait in a room with the robot that we are actually interested in getting them to engage with. This means that the participants in some way will be deceived by being observed at a point where they do not expect that they are being observed. This does raise ethical issues which is important to address in order for the study to be conducted within the confines of ethically correct research. This would have required a new ethics approval that took time which we did not have. Exploring new ways, however, to get peoples genuine natural interaction with the robot seems important to further research within HRI.

## 10.3 Conducting research

This project started out with a reasonably clear idea of where it would go, with us expecting to conduct studies with an artificially intelligent robot at a science museum and then replicate the setup in a controlled environment in order to compare results from the two settings. It turned out not to be this linear and there were quite some bumps along the way. We did not realise the scope of the project and the amount of work still needed to be put into the Articulated Head in order for it to be a functional robotic agent. Along the way we learned that conducting research outside of Denmark is quite a different matter in the sense that everything needs to be approved by an Ethics Review Board. We had planned to be able to conduct the first grounding study at Questacon within the first week which initially got delayed due to the requirement of an approved ethics application. On top of that, Questacon had their own strict guidelines for conducting research at their grounds which included a Working With Vulnerable People (WWVP) registration. This meant that a supervisor with the WWVP registration had to be present whenever any data was collected at Questacon - including asking the visitors questions at the entrance. When this was sorted, we were presented with a legal issue where our proposed research, which had been approved by the Ethics Review Board, needed to be examined by a legal department at Questacon, a legal department at University of Canberra and by Stelarc's legal team before they would allow any research to be conducted. While this was happening, we went from expecting an Articulated Head with an attention system, to an Articulated Head with people tracking capabilities, to an Articulated Head moving randomly, to settling on an Articulated Head with pre-programmed movement. In all these instances, the research design had been altered to accommodate the possibilities which the specific interaction would allow. We ended up conducting the grounding study at Questacon two weeks before hand in of the thesis.

We could not have possibly foreseen such a turbulent process and just goes to show how research in a real world setting quickly can turn into something completely unexpected which one has to adapt to, if to make any hopes of delivering a thesis within a limited time frame.

### 10.3.1 Conducting research in the wild

Moving the robot out of the lab and into the wild came with some unpredictable challenges along the way. When wanting to compare the findings from two studies, as we did in this project, it is important to be aware of the variables between the two studies beyond the setting. We wanted to control as many of the variables as possible to be able to make valid conclusions and at the same time conduct an in the wild study where the factors of the setting was taken into account.

Our discussion here is that trying to replicate a lab study in the wild is not the same as replicating an in the wild study in lab. By trying to control variables that is a natural part of the in the wild setting, the findings will be based on these conditions. Our reflection here is that it is important to be aware of what we want and should control in an in the wild setting, so we do not end up having what might be a controlled test surrounded by the wild in stead of an actual in the wild study. With that being said, it is relevant to discuss to what extend it is necessary to know the exact variable that is causing the differences or if the information of knowing that there is a difference is enough in it self.

## 10.4 Working with technology under development

The robot we used in our studies was in a state of going from one version to another, where new technologies and improvements on the old technologies were being implemented. We knew that the robot was not quite ready, when we arrived, but we did not expect not being able to see it fully functioning before our 3 months were up. A university is a complex environment where there is a lot of other stuff that needs to be attended to. We were fortunate that we could dedicate all of our time to this project, but the developers who worked hard to get the attention system to work also had a lot of other responsibilities besides this robot.

When working collaboratively with both university researchers and private companies on new technology and its implementation and testing, it is also worth thinking about which bodies are necessary to include in the decision making process so as to not delay the collaboration and work further than necessary.

We learned that when working with technology under development, not only should you expect there to be delays, but you should make sure to plan for them ahead. That means that in order to make sure to do the research that you want, you should reflect on other ways to address the same problem formulation not only to find the best but also to have other possibilities in mind if the main option fails. In this sense adaptability is highly needed.

### 10.4.1 Wizard of Oz

In our studies the robot was moving in pre-programmed loop of movements and did not respond to any interactions from the participants. If we should have tested the robot where it did respond to the participants, we found there to be two ways of doing that at the time we initially planned the studies. One way would be to test the robot with the attention system THAMBS running and the other way would have been to test the robot using the experimental technique Wizard of Oz (WoZ). We started by deciding to go with the first option and test the robot with the attention system. However, when we approached the time when the test was supposed to be conducted, the system was not ready or in a state that would make sense to test, which is a risk of working with a technology under development, as we just discussed. We therefore considered the other option of using WoZ to get the robot to respond to interactions from the participants.

The option of testing the robot using WoZ has previously been done many times in HRI according to Riek (2012). If we would have used WoZ as our experimental technique we find it important to be aware of both the methodological, ethical and engineering concerns that follows when using WoZ. Riek (2012) presented reporting guidelines for HRI studies using WoZ that they found to be important questions for researcher to consider when conducting HRI studies using WoZ. The guidelines are divided into four experimental components which is; the robot used in the study, the user interaction with the robot, the wizard controlling the robot and the last component called general which contains questions about the experiment in general.

If we reflect on these questions, that Riek (2012) encourages researcher to consider in WoZ studies, in regards of our study, we found some concerns about applying the method which eventually lead us to not using this method and instead test the robot while it was moving in pre-programmed loop of movements.

Our first concern was if it would be able for us to make the simulation convincing to the users, taken the limit time into account we did not expect to be able to do this for all participants and especially not the ones with a lot technical knowledge about robots, which there were a lot of at the UC event.

The second concern we had was the training of the wizard, again we had time as our main factor in why we did not expect the training of the wizard to be sufficient. Which would impact the behaviour of the robot and thereby participants experience of interaction with it.

When conducting studies with the goal of being able to improve the user experience of interaction with the robot based on the findings in the study, it can be an advantaged to work with the technology while it is still being developed. The reason why, is because the improvements being suggested based on the study will in most cases be faster and less consuming to implement. Especially if it is big changes that might influence other parts of the robot. With this in mind we will in our conclusion present what recommendations we will make for the further development of the AH based on our findings in our studies.

# Conclusion 11

From the findings of the two conducted grounding studies and the two conducted main studies six design recommendations is listed, that is expected to create a more convincing and engaging interaction with the Articulated Head in the context of a science museum:

- Place the base of the AH in profile position.
- Use eye contact between the robot and the user to indicated the person the robot is interaction with.
- Place the interaction in front of the robot, so the user can see the face while interacting.
- Remove the neck and shoulders on the animated head.
- Expect people will touch the robot if it is possible. Make safety precautions accordingly.
- Use virtual head animations to indicate next movement to improve predictability for the user. Expressions around the mouth and eyes are needed.

To explore if the results from studies in the lab transfers reliably to real world settings, the main studies consisted of two individual studies, one in the lab and on in the wild at a event at UC campus. The findings from the studies was compared and it was found that in both studies the participants were getting close to AH, verbally greeting the AH, asked the AH questions, mirrored the AH's movements, that eyes should control attention and that the AH had presence.

A few differences between the studies conducted in two settings were also found. The participants only touched the robot in the lab and seemed to have expectations that influenced their perception of the robot. In the wild at the UC Event, it was hard to solely recruit groups, difficult to ask all the prepared questions and more time consuming to format and prepare the data.

Our findings seem to suggest that the results from studies in the laboratory can reliably be transferred to real world settings for the majority of the findings that concentrate on human robot interaction. If participants are recruited for a lab study, they seem to enter with expectations which might influence their responses. In order to have greater confidence in these findings, more studies are needed with a greater sample size and more comparable participants, as most of what we were able to present here were tendencies.

# 12 Future work

This project was conducted as part of a bigger research project where it served as the initial testing related to the installation of the Articulated Head at Questacon. This means that our findings and conclusions in this project can and will be used in the further development of the AH as it moves from the lab into the museum setting.

Future work includes testing the AH with an attention system in different settings and conducting the study at Questacon. Afterwards it should be possible to replictae the research design in the lab. We recommend these studies to draw on the research design from our main studies and the discussions regarding this research design.

In both the grounding study at Questacon and the main studies, we have collected some data that has yet to be analysed and interpreted. It would be beneficial to conduct an analysis on the interviews and video recordings that there was not time for in this project.

Our findings and experiences from the studies we conducted is valuable knowledge for the future development of the Articulated Head as an art installation at Questacon and the research that are to be conducted with it in this setting. The experiences from applying the methods used through out this project can be valuable for future studies as they can use our work and build on top of it to conduct meaningful and important research on the interaction between humans and robots as the Articulated Head. We hope that these will be considered when moving forward.

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# Appendix

# Additional appendix data, zip-file A

This page shows the legend for the additional data that have been used for this report. The files can be found with the report in an external zip-file.

## A.1 Transcription of Interview at Questacon

## A.2 Transcription of Interview with Dr. Damith Herath

## A.3 Ethical approval for study at Questacon

## A.4 Participant Information Form and Consent Form for Studies at Questacon

## A.5 Data from Grounding Study at Questacon

## A.6 Ethical approval for studies at UC campus

## A.7 Participant Information Form and Consent Form for Studies at UC Campus

## A.8 Raw Data of the Ratings to the Godspeed

## A.9 R Script for the Statistic Analysis of the ratings from the Grounding Study.

## A.10 Transcription of Interviews at UC event

## A.11 Codes from Analysis of Videos at UC Event

## A.12 Transcription of Interviews from Main Study in Lab

## A.13 Codes from Analysis of Videos from Main Study in Lab with Focus Group

# Cognitive architecture of the FACE robot B

This section gives an overview of how the system was put together in the FACE robot using a hybrid deliberative/reactive paradigm. Figure B.1 is borrowed from Lazzeri et al. (2018) and gives an overview of the cognitive architecture and how it was connected with different modules. Here the high-level deliberative control is highlighted in the PLAN block and the low-level reactive control is highlighted in the SENSE-ACT blocks. The way the cognitive architecture is set up makes it very robust. It is able to distribute its computational workload across multiple modules which is inspired by the way the human body operates. In order to communicate between modules, a middleware is needed to facilitate this intermodular communication. In this case Lazzeri et al. chose to use YARP - an open middleware API. The I-Clips Brain controls all planning in the system including attention, emotion, and its energy distribution, (Mazzei et al., 2014). It uses CLIPS (C Language Integrated Production System) syntax (if X is true, then execute Y), which is a language developed by NASA in 1985 (`http://www.clipsrules.net/AboutCLIPS.html`). HEFES stands for Hybrid Engine for Facial Expressions Synthesis and is in charge of the emotional control and the computation of appropriate facial expressions. It receives ECS (Emotional Circumplex Space) point based on the circumplex model, (Russell, 1980).

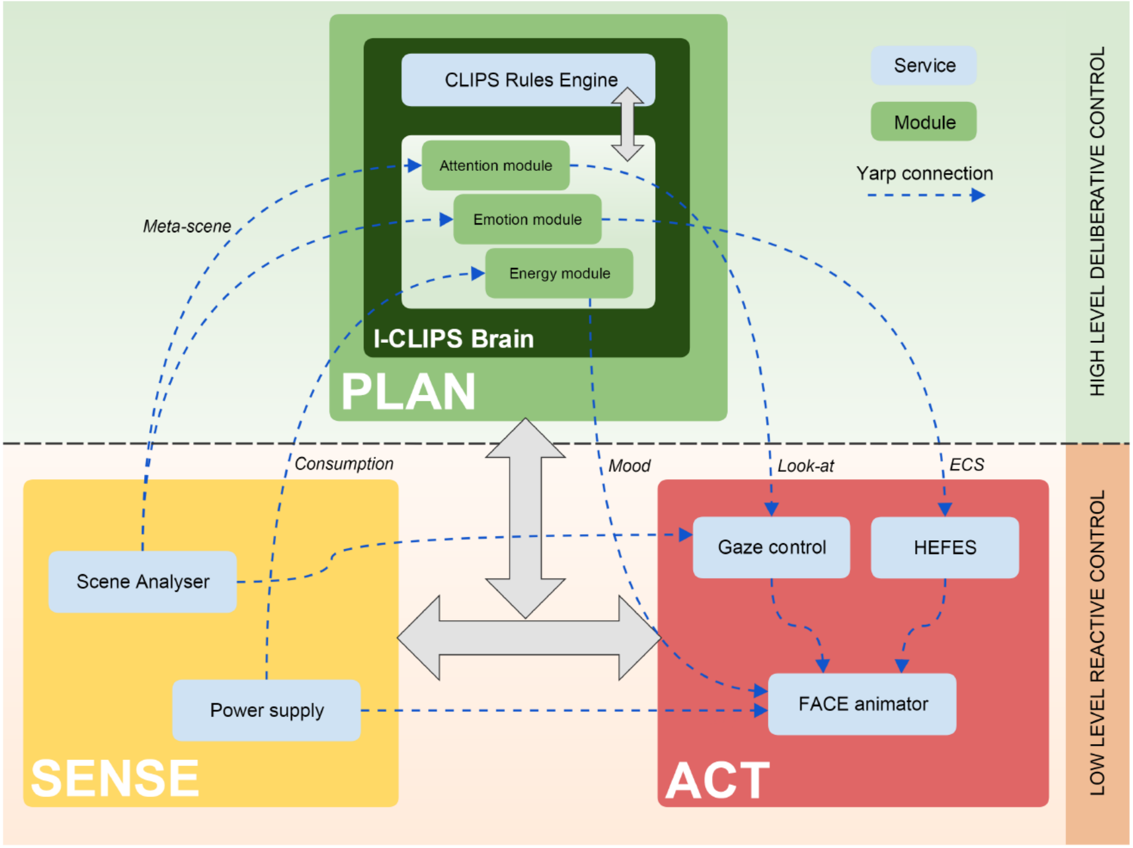


***Figure B.1.*** The cognitive architecture of the FACE robot built on the hybrid deliberative/reactive paradigm. The I-Clips Brain controls the PLAN block, is modular and is able to be setup by neuroscientists and behavioural psychologists to define its behaviour. HEFES is a software module to control the emotional states of the system. FACE animator controls facial expressions and handles conflicting inputs. Yarp is an open sourced middleware designed to control robot systems. Figure is from Lazzeri et al. (2018)

# Visit to other museums C

### Trip to The North Sea Oceanarium

Before leaving for Canberra, we arranged a day trip to the North Sea Oceanarium (NSO) in Northern Jutland in order to better understand how public institutions like museums try to convey their stories and display their artefacts. NSO is not exactly a science museum but we believed that they share the same ideology of trying to teach a younger audience about a specific area by having interactive elements and events.

When one walks in, there are immediately aquariums to see. But there is one centrepiece. A big map on a cylinder on the floor, which is crucial, as it puts the different aquariums into perspective. It is a physical model of the seabed in the North Sea and highlights the areas where they have collected their fish from and built their aquariums after. They have a guide assigned to explain about the different areas and which aquariums are representative of them. This helps to set the scene of the entire museum. They have flyers with a day programme of events such as feeding time for the seals, whale lecture, feeding time in the big aquarium with a diver etc. Throughout the exhibit there a interactive elements such as an open aquarium where children can pick up crabs, a booth where one can try and hold their breath as long as a seal, a sailboat moving in rough see, and most impressively a big interactive virtual game, where small booths allow people to control fish (from the fish's point of view) which is displayed on a massive wall. The objective in the latter is to survive and avoid becoming a part of the food chain by being eaten by a shark. This was a very popular installation.

### The Powerhouse museum

We also had the time to visit the Powerhouse museum, where Kroos, Herath, and Stelarc (2012) conducted their research using the Articulated Head. Again, this was to gain an understanding of what setting the Articulated Head would be situated in at Questacon. Here it seemed the their narratives were set in different time periods ranging from the first steam powered trains to space travel. They had one section filled with interactive installations to teach visitors about the physics of pulley systems, magnets, different material properties etc.

# Understanding the *Born or Built?* Exhibition D

To understand the purpose and idea behind the *Born or Built?* exhibition we conducted two interviews, transcriptions of both interviews can be found in Appendix A.1 and A.2. The aim of the interviews was to get different points of view on what the value of the exhibition is and to be aware of the challenges there might be. As the setting is important to the project it is necessary that we get a good understanding of it and build our decisions in our project on the right information collected from the right sources.

## Interview at Questacon with the curatorial team

In order to properly understand what Questacon and the *Born or Built?* exhibition is really about, a meeting was set up with the curatorial team of the exhibition. Present were numerous gallery assistants and concept developers from STEM backgrounds, the team leader for the concept development team, Elizabeth Jochum and Damith Herath along with the curator of The Natural History Museum of New York. Some questions were prepared beforehand, but due to the amount of attending people and the nature of the meeting, they were mostly answered as part of the dynamic conversation and without the need to specifically ask them. The questions prepared beforehand:

1. What theme/narrative are you aiming for?
2. What inspired the exhibition?
3. What value does it provide to visitors?
4. What do you hope people get from attending the exhibition?
5. What are the future plans for the exhibition?
6. What are the challenges?
7. What are your favourite elements?

The interview at Questacon is transcribed and can be found in Appendix A.1.

### What is Questacon generally about?

Some insights into the Questacon museum were gained during the conversation. Questacon accomodates between 200.000 - 300.000 people through each gallery space per year. Their strategy could be described as broad reach, low impact. Even if they only impact a small percentage of the visitors it still builds up when they have that many visitors annually. Alex Jordan, a STEM exhibit developer described that Questacon is for science what an art gallery is for art. One does not walk away from a gallery thinking that art is easy or that one can become an artist. One walks away with a new appreciation of art. In the same way they want people to come out of Questacon, not thinking that science is easy, but that science is interesting and valuable. The way they try to achieve this, is by having visitors physically immersed in the exhibits. They do not tend to give much background into the exhibits like traditional science museums. E.g. an exhibit on electromagnets do not credit its Danish inventor, Hans Christian Ørsted; it physically shows the electromagnetic effect instead. In this sense, there is a heavy focus on phenomenological exhibits.

### The ***Born or Built?*** exhibition

The *Born or Built?* exhibition was long under way and started nothing like it eventually turned out. There was a rough outline of an exhibition involving humans, robotics and prosthetics from 2015 which were picked up again in 2017. They started out with an idea of super-humans and human augmentation with prosthetics which led to humans becoming more like robots. This eventually was turned around to encompass robots becoming more like humans in stead. The Articulated Head (AH) was first included in the later concept iterations of the exhibition. At first they looked into having a live Turing test, where a visitor would chat with a human and a robot, with the idea that they would not be able to tell the two apart. They could, however, not come up with a UI that worked out and moved on. They also considered a robot that would draw a visitor's portrait, intended to spark a discussion about whether it was a printer or an artist, who should be credited etc. The budget for that eventually went into the AH in stead, when the exhibition theme was locked in.

With *Born or Built?*, Questacon has tried to create a much more contemplative atmosphere compared to their other more linear phenomenological exhibits. They had a requirement of no closed questions and leaving the answer all in the hands of the visitor. This way they would try and spark a discussion between the visitors and give them a sense of empowerment over the future. Show them that they have a say in these matters. They really wanted to put focus on the issues that society might face in the near future including the ethical intricacies surrounding social robots and AI. An interesting quote by Anita is: "Science is nothing without its context. And often that context is what makes it really interesting.".

Figure D.1 shows a layout of how the *Born or Built?* exhibition is designed. It has three rough sections with their own focus: Humans, Ethics Avenue, and Machines. In the 'Humans' area, they have exhibits regarding augmenting the human with technology.
The 'Ethics Avenue' consists of six kiosks all designed to challenge the visitor on their ethical beliefs regarding AI. Questions include whether or not it's OK to genetically alter babies in the womb, if autonomous cars should always follow the road rules, who is to blame if an artificially intelligent agent makes mistakes, whether or not AI's could be used in prison sentencing etc. At the end of the 'ethics avenue' there is an ethics wall displaying the statistics of the various visitor's answers from the kiosks to get a sense of the overall opinion. This data could prove extremely valuable in gauging Questacon visitors' immediate opinions toward AI. The questions are a different nature than the EU studies (EU, 2017)(EU, 2015) in that they are forcing people to take a stance on ethical issues that they might not have considered prior to coming to the exhibition. The kiosks

can provide more nuanced data in different concrete areas of AI compared to the EU studies. With slight modifications, the questions could be deployed to a representative population in order to get a sense of where people have strong opinions and where they are completely undecided. It would be very interesting to see the results of such a study and it could help create awareness of these ethical issues that the world either *is* facing or *will* face moving forward.
The 'Machines' section will have various robots present, including the Articulated Head. The way the exhibition is designed, there is really no fixed way through it. People are expected to move around very dynamically in the space. It is therefore not possible to know exactly which route a visitor has taken or even from which entrance they entered.


***Figure D.1.*** The ground layout of the *Born or Built?* exhibition. Graphic used with permission from Questacon.

## Interview with Dr. Damith Herath

After gaining insight from the people at Questacon about their thoughts behind the *Born or Built?* exhibition we turned to Dr. Damith Herath, who is one of the robot developers behind the Articulated Head which will be a part of the *Born or Built?* exhibition. We wanted to hear what role he plays in this, and what he expects to gain from this exhibition. Therefore, we prepared a few questions, and conducted a semi-structured interview. The questions are listed here:

1. What are your main reasons for being part of this exhibition?
2. What is new/different about this exhibition?
3. What do you see as the biggest challenges about the exhibition?
4. How do you see your role in this exhibition?
5. If any, what compromises is necessary for you to make?
6. Do you get something "extra" out of being a part of the exhibition?
7. What do you see in the future for this exhibition?

The interview with Dr. Damith Herath is transcribed and can be found in Appendix A.2.

### How Damith got involved

Dr. Herath gave the background story behind the Articulated Head (AH) ( section 2.5). Originally, Stelarc just had his Prosthetic Head but he wanted to expand this into a more robotic embodiment - purely for artistic expression. He managed to receive funding for a Fanuc LR Mate 200iD industrial arm, which he planned to use as the kinematic embodiment of the Prosthetic Head. Dr. Herath recalls that they struck up conversation and he thought it sounded like an interesting project to be a part of. Originally the plan was just for it to be a kinematic sculpture. They started working together on its movements to find what would elicit the seductive movement, that Stelarc pursued. Eventually they moved away from it being a purely kinematic sculpture to actually wanting to implement sensors to the arm and to make it a real interactive platform. This merged into the AH. They went ahead with that project and presented it at a couple of conferences. The project became a finalist in the Engineering Excellence award in innovation. Following this, the Powerhouse museum in Sydney was interested in creating an exhibition with the Articulated Head. Due to the size of the installation, they had to create a whole new enclosure. Dr. Herath and the team saw this as a great opportunity to create a live lab and do some research. The Powerhouse Museum was very open to this idea and made it happen. The exhibition ran for two years there. During that time, they explored different interactions with people but also used the AH to explore Robot Robot interaction (RRI) from a human's perspective where the AH followed a mobile platform. They experimented with turning the attention system on or off or just having a vision tracking system without any intelligence following the mobile robot around. They found that people were remarkably able to tell when the attention system was turned on or not.

These were the kind of ideas that Dr. Herath's team wanted to explore, but funding ran out. He then went on to start a company with others from the team. Three years ago he got a chance to come back to work with HRI and ran a couple of HRI experiments at Questacon. One of which won an award for Best Interactive Session Paper Award.

### What is different this time?

He heard that Questacon was planning on doing the *Born or Built?* exhibition and he pitched the AH to them which he believed would add value and fit in well with the rest of the exhibition. It was an opportunity to create a living lab again. A lot of technical advances have happened since then. A part of an unencumbered interaction, that Stelarc pursued, is to communicate directly through speech in stead of typing. Back in 2010-12, the speech recognition software was not precise enough, but now it averages between 90-95 percent. The most obvious difference this time, compared to the Powerhouse museum exhibit, is the robot arm. Last time they used the industrial Fanuc arm which had to be fully enclosed for safety reasons. This time they use the UR10 collaborative robot. Stelarc wanted a really intimate interaction without any barriers which previously was not possible, but now seems a lot more feasible with this new arm. In an industrial setting you are able to be working with a UR10 without any barriers. There are, however, no guidelines regarding public settings. These are some of the things Dr. Herath wants to explore.

### What are the biggest challenges?

Dr. Herath believes that ultimately the challenges are the same as in the previous installation at the Powerhouse museum. A very important factor is the safety of the robot. Especially in this setting where there really is no precedence of how to set up a live robot installation without any physical barriers. In addition to this, there are a lot of technical challenges. E.g. how to ensure that the installation will be able to run 24/7 for a couple of years. Dr. Damith recalls how some people reacted to the last exhibition at the Powerhouse museum. There was a strong excitement factor around a seemingly conscious, live agent. People who regularly interacted with it maintained that sense of agency, which was good, according to Dr. Herath. On the topic of agency Dr. Herath said an interesting quote: "Obviously It's not a conscious agent it's just a patch of code.". So after having established the safety criteria, the next step would be to understand these interactions and what they mean to humans, along with any ethical questions which might arise from that.

### Regarding compromises

Dr. Damith and his team has always tried to push for minimal distractions or barriers. In this case, it might not be possible to remove the barrier completely due to the settings and safety requirements from the museum. So they might have to include some form of barrier. They are, however, experimenting with a no barrier installation at ICRA 2019 in Montreal, Canada (`https://www.icra2019.org/` [1]).

### Future of the art installation

They certainly want to increase the capabilities of the robot. As of now, the attention system (THAMBS) runs on a simple probabilistic model. His team wants to implement some of today's advanced deep learning techniques and introduce a long term memory system in the robot so that it will be able to remember past interactions and learn from them. Normally, learning in Artificial Intelligence is constrained to a specific context such as learning to recognise human faces, but Dr. Herath thinks this could be utilised in a broader sense to learn from interactions. E.g. The last time it responded or moved a certain way, it elicited a unique response in the human, which it can utilise in future interactions. This could allow it to develop socially as well.

[1] Accessed 2019-04-10

# E Godspeed original and revised

**GODSPEED I: ANTHROPOMORPHISM**

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

| | | | | | | |
|---|---|---|---|---|---|---|
| Fake 偽物のような | 1 | 2 | 3 | 4 | 5 | Natural 自然な |
| Machinelike 機械的 | 1 | 2 | 3 | 4 | 5 | Humanlike 人間的 |
| Unconscious 意識を持たない | 1 | 2 | 3 | 4 | 5 | Conscious 意識を持っている |
| Artificial 人工的 | 1 | 2 | 3 | 4 | 5 | Lifelike 生物的 |
| Moving rigidly ぎこちない動き | 1 | 2 | 3 | 4 | 5 | Moving elegantly洗練された動き |

**GODSPEED II: ANIMACY**

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

| | | | | | | |
|---|---|---|---|---|---|---|
| Dead 死んでいる | 1 | 2 | 3 | 4 | 5 | Alive 生きている |
| Stagnant 活気のない | 1 | 2 | 3 | 4 | 5 | Lively 生き生きとした |
| Mechanical 機械的な | 1 | 2 | 3 | 4 | 5 | Organic 有機的な |
| Artificial 人工的な | 1 | 2 | 3 | 4 | 5 | Lifelike 生物的な |
| Inert 不活発な | 1 | 2 | 3 | 4 | 5 | Interactive 対話的な |
| Apathetic 無関心な | 1 | 2 | 3 | 4 | 5 | Responsive 反応のある |

**GODSPEED III: LIKEABILITY**

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

| | | | | | | |
|---|---|---|---|---|---|---|
| Dislike 嫌い | 1 | 2 | 3 | 4 | 5 | Like 好き |
| Unfriendly 親しみにくい | 1 | 2 | 3 | 4 | 5 | Friendly 親しみやすい |
| Unkind 不親切な | 1 | 2 | 3 | 4 | 5 | Kind 親切な |
| Unpleasant 不愉快な | 1 | 2 | 3 | 4 | 5 | Pleasant 愉快な |
| Awful ひどい | 1 | 2 | 3 | 4 | 5 | Nice 良い |

**GODSPEED IV: PERCEIVED INTELLIGENCE**

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

| | | | | | | |
|---|---|---|---|---|---|---|
| Incompetent 無能な | 1 | 2 | 3 | 4 | 5 | Competent 有能な |
| Ignorant 無知な | 1 | 2 | 3 | 4 | 5 | Knowledgeable 物知りな |
| Irresponsible 無責任な | 1 | 2 | 3 | 4 | 5 | Responsible 責任のある |
| Unintelligent 知的でない, | 1 | 2 | 3 | 4 | 5 | Intelligent 知的な |
| Foolish 愚かな | 1 | 2 | 3 | 4 | 5 | Sensible 賢明な |

**GODSPEED V: PERCEIVED SAFETY**

Please rate your emotional state on these scales:

以下のスケールに基づいてあなたの心の状態を評価してください。

| | | | | | | |
|---|---|---|---|---|---|---|
| Anxious 不安な | 1 | 2 | 3 | 4 | 5 | Relaxed 落ち着いた |
| Agitated 動揺している | 1 | 2 | 3 | 4 | 5 | Calm 冷静な |
| Quiescent 平穏な | 1 | 2 | 3 | 4 | 5 | Surprised 驚いた |

***Figure E.1.*** The original Godspeed questionnaire from Bartneck et al., 2009

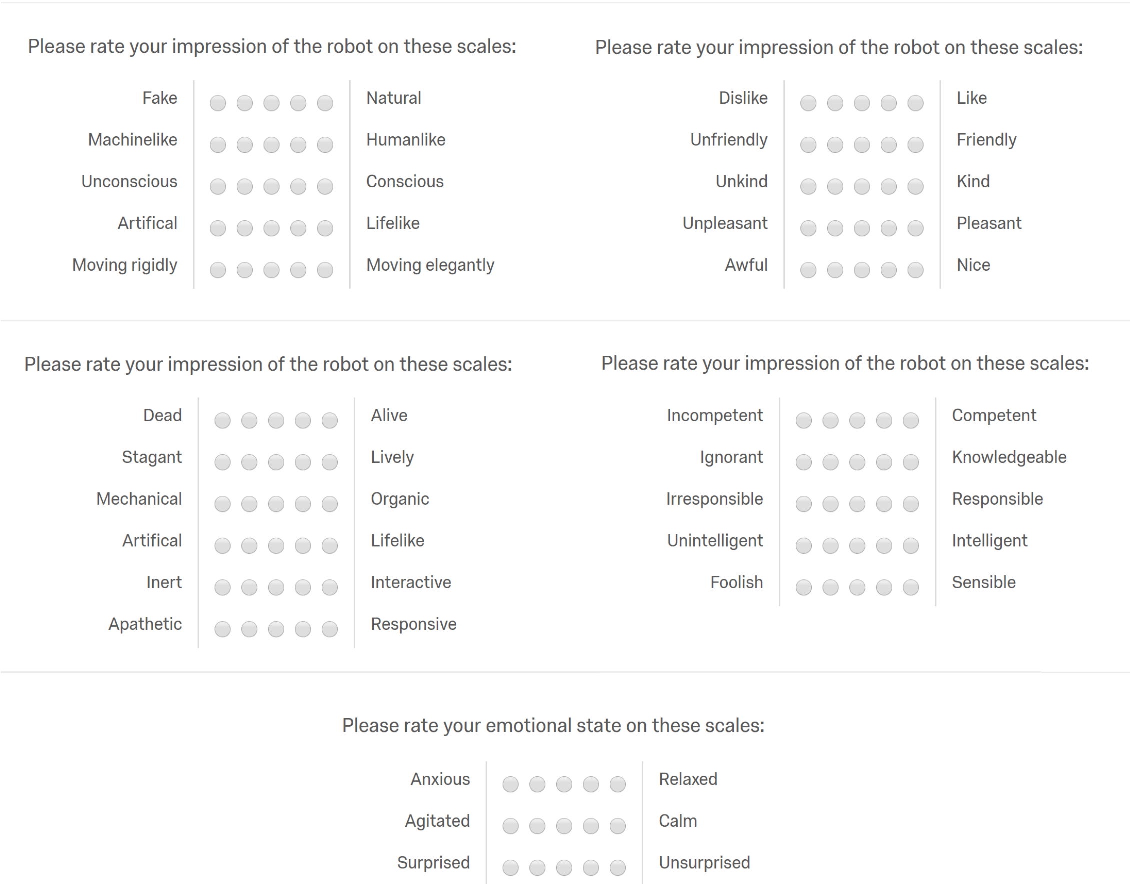


***Figure E.2.*** Our slightly revised version of the Godspeed questionnaire. Swapped the endpoints in the last question about perceived safety and renamed "Quiescent" to "Unsurprised"

# F Thematic Maps

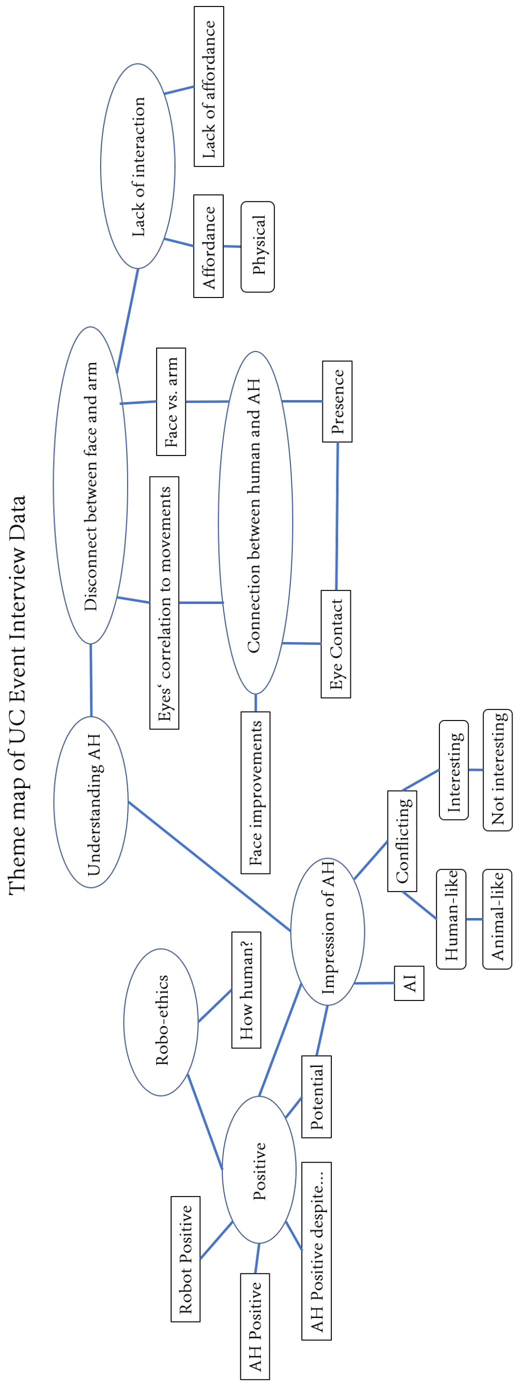


***Figure F.1.*** Thematic map from the UC Event, based on the interview data.

# Possible Applications for AH - Mentioned in Main Studies G

**From study at the UC event:**

- A companion in space. Mentions the IBM Watson Space Robot.
- Work as a interesting lecturer. Teaching remotely in a interesting way. Be in two auditoriums at once.
- Giving a speech - moving around and talking to the crowd. Could be to make the crowd more engaged in what the speech is about - relates back to teaching. Suggests trying to give new life to a youtube video (e.g. from VSauce) by synching the speech with the robot and its movements.

**From study in lab with focus group:**

- As a icebreaker, to help start a conversation.
- Being a scanning and viewing device.
- AH could be used as a distraction in a childcare center or dementia unit.
- AH could contribute to a sense of security at nursing homes. If one falls, it might sound an alarm.
- In Prison designs, to give the feeling of being watched. To make the prisoners believe that they are or could be watched. Quote: *"Changing the hole effectiveness of surveillance, that that could be really important. Just something that was moving that actually recorded sound and [light]. And didn't necessary interact with human, you wouldn't know.. You wouldn't necessary know that it was or wasn't. And it would make you careful and apparently this is true – This could be a very interesting application."*
- As an avatar presenting diversity(cognitive diversity) in a meeting to thereby improve logic processes and make the people come up with better solutions. This idea is based on the book "Which of two heads is better than one?" by Juliet Bourke. Quote: *"Apparently cognitive diversity is triggered when you have anything that looks like it's different as in humans. So it could be a different gender, but we know that's sort of basically developed over – it's developed culturally. So that's one. The other one is skin color, language but also accent and that sort of thing. So if you had a group of people who was all sort of a single type, just the fact that there was several of some other type in the room makes them more careful in terms of their judgements and makes them more reflective in terms of what they say. And it starts to [trigger out those sorts of agrotypes] so they care in there logic processes and they come up with*

*better solutions. So in other words, you could have an avatar that was an Indian woman in the room or the sense of the Indian woman in the room and people will start to thinking and talking in different ways because there is an Indian woman in the room even though it's not an Indian woman.“*