Development of a Social Robot Toolkit for Co-Design and Prototyping

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Abstract

With the rise in the use of social robots in society also comes the need for a tool that Human-Robot Interaction (HRI) developers can use to build social robots more effectively. To develop effective social robots, these developers often create robots through the practice of co-design. This tool that HRI-developers would be able to use can be in the form of a social robot prototyping toolkit that facilitates rapid prototyping and can be implemented in co-design. By providing them with such a tool, it could contribute to the efficiency and effectiveness at which the social robots are developed. The focus of this bachelor thesis project is to develop such a tool that HRI-developers can use. This paper discusses the methodology taken to realize such a toolkit and evaluates its effectiveness through user evaluation. Ultimately a social robot toolkit was created that facilitates on the spot construction and provides HRI-developers with the basic tools for creating only simple social robots. These range from different hardware components to components used to connect these to form a full prototype. It was found that such a toolkit automatically functions as a possible tool for educational purposes when allowing entry-level users to use it, or when used in co-design with entry-level users. Another important finding is that the constructing components of the prototype toolkit can also be used as a means for stimulating participant engagement during co-design. Additionally, the research suggests that when developing such a social robot toolkit, it is also important to provide the toolkit users with a singular coherent programming IDE to program the behavior of the prototype more effectively and efficiently.

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Contents

1 Introduction

This chapter will focus on describing the context of robots within the social domain and the relevance of a social robot toolkits within the field. Afterward, the challenges will be discussed that arise with the development of a social robot toolkit. Subsequently, the main research questions will be addressed that assist in tackling the previously mentioned challenges.

1.1 Background

Nowadays, the relevance of robots in the social domain keeps increasing in terms of their role in personal, professional, and public assistance [1]. This results in robots not only needing to comply with industrial needs but also human-centered needs and subsequently influences the way that robots in the social domain are developed. Similarly, Campa [2] argues that the field of robotics is also already expanding towards the field that will require methodological collaboration between the fields of engineering and sociologists. This is due to the developments within the fields of engineering, which subsequently allows for an increase in robot functionality. It is this increase in functionality which then leads to robots becoming more sophisticated and subsequently results in engineers needing to be trained by sociologists and psychologists to make more effective social robots.

In other words, due to human-robot interaction, the robots have to take in a lot of the feedback created by the human and react accordingly. One of the major aspects that makes it relatively difficult for robots to socially connect with humans, is that humans are different from each other. Different personalities among humans mean that their preference for what they prefer connecting to socially and emotionally is also different. Similar to how certain people prefer dogs over cats, some prefer cats over dogs, some prefer both, and some neither as social companions [3]. Some people enjoy having active conversations with their social companions, whereas others prefer to mainly listen. It is this difference in user-based personalities that encourages the HRI (Human-Robot Interaction) developers to develop these robots through a series of co-design or participatory design methodology [4]. By developing social robots with their potential end-users, HRI developers can ensure that the social robot they created fits the requirements of the end-users. However, these co-design sessions in which the HRI developer and potential end-user interact with each other cannot last longer than a certain amount of time [5], because, after a certain amount of time, the users might start to get bored, annoyed or tired, resulting in them giving less relevant feedback for the design. As a result of this, HRI-developers are required to quickly adjust their social robot prototypes in order to get as much relevant feedback from the co-design participant during the co-design sessions as possible. This also indicates for the developers of these robots that they should quickly be able to adjust the design and concept of the social robots to fit the end-users means and is the reason why the development of such a social robot toolkit is the main goal of this project. With toolkit is then meant a construction set that contains the components needed to build the desired prototype, and would allow people to develop different social robot concepts more efficiently during co-design sessions.

1.2 Objective, Target Users & Challenges

1.2.1 Objective

The development of a social robot toolkit that facilitates rapid prototyping during co-design comes as objective comes with its challenges. After defining these different challenges, they can be summed up and translated into one main research question. The conclusion and discussion from this research would then be the answer to this main research question. Additionally, this main research question could then be further divided into several sub-research questions from which the answers contribute to answering the main research question. These challenges must be overcome to reach the objective of the project, which is to provide the target group users with a social robot toolkit that can be used in the design and co-design of social robots.

1.2.2 Target group

So far the target group of the social robot toolkit is described as HRI-developers. These developers can be described as people that need to build a social robot prototype. It is important to note that people who have to create social robots can have different reasons for doing so. These could range from work-related reasons, to school-related reasons, to personal reasons, and could age from anywhere between age 10 to age 50. This results in the target group possibly having not one specific educational background and comes as its own additional challenge for the project.

1.2.3 Challenges

First and foremost, the toolkit should provide the developers with the basic requirements that make it possible for the robot to be social. By doing so, it is possible to ensure that a majority of the HRI-developers will be able to develop a social robot prototype that fits the needs of the end-user without having to add additional materials or components.

Secondly, the components within this social robot toolkit should easily be interchangeable for the developers to be able to rapidly prototype and change the design and features, thus also encouraging the developers to further tinker in the development process. By doing so, the social robot toolkit would facilitate rapid prototyping.

Thirdly, the HRI-developers should be able to further customize each of the components present in the toolkit if they wish to do so. This would allow them to create an even more possibly complex social robot prototype, or one that can better fit the needs of the end-user.

Fourthly, the social robot toolkit should be usable for a generic end-user, no matter their educational or career background.

1.3 Research Questions

1.3.1 Main research question

All the previous challenges mentioned in *1.2.3* can be translated into one single main research question for this project. This main research question could be described as:

How to develop a toolkit that facilitates the rapid prototyping of social robots in a co-design scenario and is usable by entry-level users?

It is important to note, the with “develop” in the main research question is meant the outcome of the design, rather than the design process. To answer this main question, several sub-questions will need to be answered first. These will be answered through a literature review, to get a better overall better understanding of the field of social robotics and co-design. The knowledge gained from this literature review will function as a foundation and guideline for the realization of the social robot toolkit prototype. From this, a prototype can be developed as the “hypothesis” to this main research question, saying “this is a way” given the previously mentioned challenges. This would then go through a user evaluation to test whether this prototype of the toolkit is a correct answer. How this will be tested, is described in detail in the method(s) of the user evaluation. The initial part of the process of defining the research questions can be seen in figure 1 on the next page.

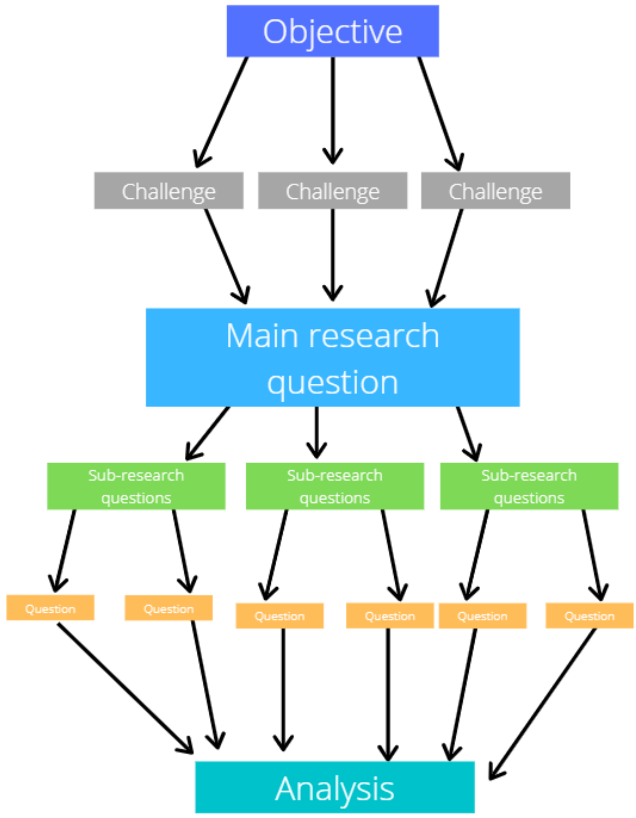

Figure 1: Initial part of the process that will be taken into reaching the objective. The continuation of this process can be seen in figure 13.

1.3.2 Sub-research questions

To answer the main research questions, several sub-questions must first be answered in a literature review. By answering these questions, a deeper understanding of the field of social robotics and co-design will be acquired.

To get a better understanding of the field of social robotics, one must first have an overview of the different types of social robots and determine what characteristics are relevant for effective human-robot social interactions, to ultimately answer the question *What characteristics make a robot effective in a personalized social interaction?* This first sub research question can be even further divided into a series of sub-sub research questions. These are:

1. What types of social robots are there?
2. What should social robots look like?
3. What causes successful social interactions between robots and humans?

Secondly, because another objective of this toolkit is to be used in design and co-design, the second main question that has to be answered is *How can construction sets be used in effective co-design?* To address the second sub research question, 2 sub-sub-questions were formulated:

1. What makes a construction kit engaging for co-design?
2. How can a construction kit promote creativity among the users?

Thirdly, after identifying the relevant characteristics needed for both effective social robots and effective co-design, these should be ultimately realized into one product, which is the toolkit for designing and developing social robots. This toolkit will consist of the components needed to realize the social robot. However, to make such a toolkit, one must have a basic understanding of the physical components needed to realize the social robot. This leads to the question *What components can be used to facilitate effective co-design and embed effective characteristics for personalized social interaction?* To address the third main research question, 4 sub-sub-questions were formulated:

1. What components are mostly used for social robot input?
2. What components are mostly used for social robot output?
3. How is the information gathered from components processed?
4. How should these components be connected to form an overall effective embodiment of social robots?

The sub-questions will be explored and discussed in a review of current literature in the form of qualitative research. After discussing the results found to the sub-sub-questions, the sub-research questions will be answered in the discussion and conclusion. These findings will function as the starting point and guideline for the proceeding development of the social robot toolkit.

2 Analysis: A literature review[1]

This chapter of the report will focus on answering the previously mentioned questions. This chapter is divided into five sections. The first section will first focus on the taxonomy of social robots in society. Afterward, it will focus on identifying the relevant characteristics that cause effective social interactions with humans by focusing on appearance and behavior. Then, the second section will focus on increasing the effectiveness of co-design. Afterward, the third section will focus on identifying what physical components can be used to realize the previously mentioned characteristics and combining them into a fully embodied social agent. Then, the fourth section will look at current practical examples of social robot toolkits. The goal of this final section is to find additional inspiration and guidelines that further be used in the development of the social robot toolkit. Findings and what they mean for the project can be found in the last section, which is the "Conclusion of the Literature Review".

2.1 Taxonomy and Relevant Characteristics of Social Robots

2.1.1 Types of social robots

Interactive robots can be placed into different categories that define their role within the social domain. To properly categorize these robots, Fong, Nourbakhsh, Dautenhahn [1], and Breazeal [6] look at the way that they interact with humans. In their reports they categorized these into socially evocative, social interface, socially receptive, sociable, socially situated, socially embedded, and socially intelligent robots. Socially evocative robots are agents that depend on mankind their tendency to anthropomorphize and take care. Social interface robots specialize in making use of human-like communication methods and social cues however, this behavior is only modeled at the interface and they have shallow models of social cognition. Socially receptive robots are passive agents that require human behavior as input so that they can learn, whereas sociable robots pro-actively interact with humans as they are programmed to do so. Socially situated robots are agents that perceive and react to the social environment that they are in, rather than another human that they interact with. Socially embedded robots are slightly more complex compared to socially situated robots, these also structurally coupled to their social environment and are somewhat aware of the humans' input in the environment. Lastly, socially intelligent robots are agents that have

[1] Section 2.1 also done for Academic Writing in Creative Technology module 11.

advanced models based on human cognition and social competency. These robots are so advanced that they show intelligence on a human level.

However, Hegel, Lohse, and Wrede [7] categorize social robots into more general and categories that not only depend on the interaction with humans but also their general appearance. These two main categories are humanoid robots and nonhumanoid robots. As the name suggests, humanoid robots are agents that are designed with more human-like appearances and are used in business, security, healthcare, personal assistance, teaching, transport, caregiving, and public assistance. Non-humanoid robots are also referred to as animal-like robots and are mainly used to serve as companions, entertainers, toys, and pets.

Lastly, Aslam, van Dijk and Dertien [8] categorize them in a function-oriented way, by classifying social robots according to their tasks and focus. According to them, three main categories that social robots can be classified into are functional/domestic robots, assistive social robots, and generic social robots. Functional/domestic robots assist their users in their tasks in order to advance productivity. Assistive social robots give their cognitive assistance as well as physical assistance. These can range from helping e.g. autistic children develop their social skills to helping the elderly receive their medication. Lastly, generic social robots have tasks and interactions depending on their focus, which can be human-focused, robot-focused, and environment-focused interaction.

2.1.2 Outward aspects and presentation of social robots

After having explored the different types of social robots, it is also important to explore their appearance. Fong, Nourbakhsh, and Dautenhahn [1] argue that there are four main designs that a robot can have. These are anthropomorphic, zoomorphic, caricatured, and functional designs. Anthropomorphic designed robots are agents with recognizable human-like features in their appearance, such as eyes and ears at the same height as that of humans. Zoomorphic designs are agents with recognizable animal-like features in their appearance, such as walking on four legs. Caricatured designed robots are agents that do not have a realistic humanlike or animal-like appearance. Their design has stereotypical representations and their appearance can distract or put attention to certain robotic features. Lastly, functional designs are designs that have no appearance choices that were made in order to appeal to humans. Their design is completely dependent on their task or functionality. Additionally, they also state that for social interactions with humans, a more anthropomorphic design is required for the robot, since humans are social experts and mostly socialize with other humans themselves. Humans also tend to judge the functionality of the robot on its appearance, and if the robot looks humanlike, the humans will more likely also associate it with socializing.

On the other hand, Kanda, Hirano, Eaton, and Ishiguro [9] state that when designing social robots the developers should keep in mind that in order for the user to connect socially with the robot, the robot and the user must share some common ground. This is why they also suggest using a humanoid design approach when designing a social robot. They claim that this design is good for social interaction with humans because it has a higher chance for the user to establish common ground with the social robot. Hegel et al. [7] further elaborate on this by stating that the design of the robot is influenced by the expectations of the person interacting with it. It is, therefore, according to them important to also include human-likeness rather than animal-likeness physical appearances in the design of the robot in order for it to be perceived as a social agent they can interact with.

Although the appearance of social robots prefers a humanoid design, research done by Lakatos et al. [10] suggests that non-humanoid appearances can still cause some forms of emotion attribution with humans in social situations. During this study, the non-humanoid designed social robot still did have a lot of animal-like features. However, participants in their study could still understand the emotional expressions from the agent even though it was inspired by non-human behavior. Their study “provides additional evidence for the general effectiveness of human-robot interspecific relations” [5, p29]. Similarly, Aslam, van Dijk, and Dertien also argue that humanoid and anthropomorphic designs come with their downfalls, and by using a nonhumanoid design for a social agent you can avoid these downfalls. One of the major downfalls is the so-called “uncanny valley” [11], the idea used to visualize that at some point a dislike for a humanoid robot arises as it more closely resembles a real human. Humans often then describe this “dislike” as eery and human-like, yet still distinct. An additional downfall is caused by the expectations that humans create when interacting with a robot that is a combination of a humanoid and another organism or object. These are some of the difficulties when choosing a humanoid design and why non-humanoid design for social robots can still be used.

2.1.3 Robot behavior for effective social human-robot interaction

Other than appearance, some behavior aspects of these robots may influence the effectiveness of human-robot social interaction. Fong, Nourbakhsh, and Dautenhahn [1] state that human-oriented perception is key for natural human-robot interaction. The robot itself should be able to read social cues given by the human and perform accordingly in real-time and that robotic autonomous capabilities influence the effectiveness of their overall social interaction with humans. They allow the human to acknowledge that the robot itself does not only want to focus on tasks but also let the robot participate in the richness of human society. In addition to this, Arkin, Fujita, Takagi, and Hasegawa [12] suggest that robots should also have their own “ethological model and emotional model”. They claim robots themselves should have the ability to learn and should also have internal and external motivations. Similarly, Sheridan [13] found that making appropriate gestures, recognizing speech, making decisions and learning are important for effective social interactions. They believe that pre-defined mental models combined with computational models “will have safety and efficiency benefits in human-robot systems”.

Furthermore, Fischinger et al. [14] indicate that care robots should be able to safely navigate their environment, detect and track humans, recognize gestures, grasp objects and entertain users in order to be socially accepted by the humans. This was because of people their tendency to initially underestimate the capabilities of the robot, but once the robot showed that it could fulfill their designated tasks, its social acceptance rate increased. Ghazali, Ham, Barakova, and Markopoulos [15] also elaborate on this by suggesting that being able to trust the robot and liking it contribute to effective social human-robot interaction. Similar to Fischinger, they found that being able to trust the robot in fulfilling its designated task increased the appreciation of the robot and subsequently also increased the trust that the user had in the robot and therefore also increasing its social acceptance.

2.2 Effective co-design for a social robot toolkit

When developing a social robot toolkit that is to be implemented in the context of participatory design, it is also important to look at how effective co-design and creative scaffolding can be explored within the domain of social robots. The goal of this section is to get deepen the understanding in the field of co-design to ultimately be able to understand the scenario in which the social robot toolkit would be used.

2.2.1 Promoting user engagement in co-design

The participatory design of social robots is a design method that relies on two major parties. These two are the designers and users. By using this toolkit, the HRI-developers would be able to gain more insights into the requirements and goals of the potential end-user they are building the prototype for. This is why the engagement between the users with the toolkit is important and should be of high priority. Lee [16] argues that it is important to minimize or remove the barrier of knowledge between the designer and the user to create an overall more engaging experience. A reoccurring problem is that the users themselves sometimes lack the knowledge to further engage with a robot construction kit. This implies that the users' engagement is heavily dependent on the designer, further entailing that it is required from the designers to have a certain amount of knowledge concerning their users if they wish for a reasonable amount of engagement. This knowledge about the user should be used to understand what they don't comprehend, and finding a way to effectively explain it or work around it.

Similarly, both Lee [16] and Thinyane [17] state that the removal of these barriers is important for effective co-design. Thinyane further states that working within a group project language, culture, knowledge, and power dynamics can have a major impact on user engagement. These barriers could cause difficulties in collaboration between designers and users, and amongst users themselves when communicating with each other. It is therefore also important to remove the barriers when co-designing to get as many insights into the users' needs as possible. When these barriers are removed, the users and designers can more easily communicate and understand each other, therefore causing them to be more socially connected, which is also an important factor to consider when using scaffolding and co-design methods [18]. This increase in ability to easily communicate from designer to user, and between users increases the effectiveness of co-design by increasing the user engagement, however it could also possibly result in a decrease in the diversity of insights given. This is because these people are more socially connected, resulting in them having a very similar mindset, which causes less diversity in opinions and feedback.

Additionally, Vandevelde [19] and Thinyane [17] argue that giving the user some sense of control during the co-design process will also most likely increase user engagement. Vandevelde argues that this could be achieved by making the construction toolkit in a way that it gives the user the ability to build and hack the toolkit and it's components in ways and difficulty levels that they prefer.

2.2.2 Encouraging user creativity

The goal of this social robot toolkit is to not only engage the user into creating artifacts but to also encourage and support them in exploring ideas hidden in their constructions. It is not only relevant for the users to engage in co-designing the social robot toolkit, but it is also important to ensure creativity is stimulated among them. This is because idea generation, in other words, ideation, is critical in the design of coming up with new and possibly more effective types of social robots and to give more insight into the development of social robots in general. Different design approaches often note the relevance of creativity within the design process [20]. This can be done in different ways, for example, user creativity can be promoted by allowing the users to sketch or write down all their ideas, no matter if they're good or bad [21]. By doing so the users can generate a large number of ideas, from which a few, or a lot could be really good. This was also an effective method used by Rose [18] when co-designing social robots with teenagers. Allowing them to first sketch out all of the types of social robots allowed the teenagers themselves to think more about the different possibilities and features of the robot, ultimately contributing to the creativity used within the project. Then after mapping out the different ideas, these can be looked at and further analyzed. This way, bad ideas get indirectly removed, and good ideas will be further explored.

Additionally, Bjorling [22] argues that it to promote user creativity, the designer and participant should follow a semi-structured design process, and fully avoid following a fully structured design process. By avoiding taking pre-defined steps during the design procedure, the user can provide more creative input. When promoting creativity amongst users, research has also shown that it is important that the tools are easy to start using as a beginner. However, they should also be usable for the more advanced or experienced users and should contain a set of features that are capable of supporting a wide range of possibilities concerning creation [23]. Also, allowing users to easily backtrack and undo design choices contributes to creativity. This ensures that they should not be afraid of the consequences moving forward in the design process, as they can always easily go back.

2.3 From characteristics to hardware

After finding the relevant characteristics needed for both social robots and the toolkit that facilitates co-design, a way to physically realize this needs to be further explored. For the first two sections, the main focus will revolve around the input and output components needed for effective social behavior and looks. These will be placed in table 1 and table 2 for a better overview. The second part will mainly focus on combining these into a complete and effective fully embodied social robot and take into account the users centered requirements for keeping it as socially interactable and also encourage engagement and creativity during the design and construction process.

Note that for all input and output components, a power source and a processing module is needed. Similar to living organisms, social robots also need a power source that allows the components to function. The processing module then functions as the brain and thus has the goal is to make use of the data received from the inputs, process that information (think), and proceed to control the output components accordingly.

2.3.1 Components for effective social robot input

For this section, different research papers that revolve around the topic of social robots will be looked at. Another criteria that these papers meet is that the input components have to be specifically mentioned in a table, figure, or text of the research paper. The goal of this is to be able to make a general overview of the most common input components that are used in social robots. The results can be seen in Table 1 below. Note that recurring components will not be placed multiple times in the table.

Table 1. List of most commonly used input components for social robots.

Input	Description and goal	Source
Touch sensors	The touch sensors were used to measure whether the social robot was being touched or not. Where these sensors were located could also indicate where the robot was being touched. This contributes to the robot's ability to feel certain social cues.	[24]
Camera (Kinect)	The (Kinect) camera combined for more effective seeing capabilities for the robot. Similar to how humans and animals can see. This also contributes to the robot's ability to perceive social cues.	
Potentiometers	Used for sensing the rotation of the limbs of the robot to make more accurate and realistic movements.	[25]
Switches & contact sensors	Are used to measure whether the robot comes into contact with a physical object. The goal of these is to function as a means for object avoidance.	
USB ports	Allowed for additional USB - connectable components. (These could be for powering other components like e.g. speakers and processing modules).	[19]
Wi-Fi-module	It allows for network communication. It allows the social robot to retrieve data from the internet. This data could assist in decision making or could serve as information that could be given to the user interacting with the social robot.	
Touch sensors	The touch sensors were used to measure whether the social robot was being touched or not. Where these sensors were located could also indicate where the robot was being touched. This contributes to the robot's ability to feel certain social cues.	

Inertial sensor unit	Used to measure the orientation of the social robot. Which can further assist in measuring the geometric situation of the robot. This information would subsequently then be used to contribute to the robot's realistic or convincing movements.	[26]
Wide-angle camera	Camera modules were used for sight, that contributed to the robot to perceive its environment and the objects within it, to assist in increasing the effectiveness of social robots.	
Microphone	Social robots should be able to hear the sounds coming from their environment, to be able to know what to do accordingly. This contributes to the robot's ability to understand vocal input correctly.	

2.3.2 Components for effective social robot output

For this section, different research papers that revolve around the topic of social robots will again be looked at. These follow the same criteria as the previous section in the sense that the papers also specifically mention the component in a table, figure, or text. The goal of this is to be able to make a general overview of the most common output components that are used in social robots. The results can be seen in Table 2 below. Note that recurring components will not be placed twice in the table.

Table 2. List of most commonly used output components for social robots.

Output	Description and goal	Source
Motion actuators	The motion actuators are mostly used where the robot would require rotational movements for example for limbs. These could contribute to the realistic or believable movements of the robot.	[24]
LEDs (matrix form)	LEDs are used in this case for the robot's eyes and eye-related gestures. Giving the users the illusion of the robot looking around, which is more “life-like”, relating to it being perceived more social.	
Speakers	Speakers allowed the robot to communicate verbally, similar to how living beings do. Allowing the users to talk to it and receive vocal output in return.	
Motion actuators	The motion actuators are mostly used where the robot would require rotational movements such as at the limbs. These could contribute to the realistic or believable movements of the robot.	[25]
RGB LEDs	LEDs are used in this case for the robot's eyes and eye-related gestures. Giving the users the	[19]

	illusion of the robot looking around, which is more “life-like”, relating to it being perceived more social. Additionally, these allow for additional interaction capabilities through emotional expression. This can be done through either LED color or LED intensity.	
Speaker	Speakers allowed the robot to communicate verbally, similar to how living beings do. Allowing the users to talk to it and receive vocal feedback in return.	
Smart actuators	Similar to motion actuators, these were placed where the robot would require rotational movement, such as in the joints of the limbs of the robot. These would contribute to the robot being able to move in a more lifelike or believable manner.	[26]
LCD screen	The LCD screen was used as the robot's entire face. Compared to using a combination of a large number of actuators for facial expressions, it was believed that using an LCD screen for the robot was enough for the robot to be able to give the needed facial expressions.	

2.3.3 Processing of the data

This section will explore the figurative “bridge” between the input and the output. With this is meant how the input is processed into the proper output. During this paper, the same literature documents will be analyzed to find out how the information is processed.

Output	Description and goal	Source
PPLM/PPLP combined with the Unscented Kalman Filtering technique.	Set of software architecture that takes in the data per component/driver, and translates it to a proper output using a flowchart system.	[24]
MOSFETs (metal–oxide–semiconductor field-effect transistor)	Are used for effective component control. Assists in what component does what. Note that this is not per se an input component, but a component that contributes to the processing of the information.	[25]
Arduino microcontroller	Component control. Calculation of data to be able to know what to do. No specific choice making architecture mentioned	
Raspberri Pi	A mini computer that is capable processing the data it receives from sensing, then translates it into an output depending on the code. No specific choice making architecture mentioned.	[19]

Arduino based + GPL V3 for programming	Arduino is used to control how the input relates to the output of the robot. GPL V3 is used by for programming and they claim that it is entry-level user friendly, and still allows for more advanced robotics.	[26]

2.3.4 Combining the components into a full embodiment of a social robot

After identifying all of the relevant components that would be required to be in a robot toolkit for personalized social interactions, they should be connected in a way that where they embody the robot without conflicting with the needed social robot appearance. Ramey [24] preferred using a full embodiment for their social robot Mini. All of the components consisted of singular parts, which limited the movement capabilities of the robot but contributed to the robot seeming as if it were one peace. The arms, body, and head were given a furry textile pattern, to make it seem more likable. Holland [25] and their team used a different way to connect the components for their social robot. Their method of connecting these components consisted of finding the components they wanted to connect and designing appropriate connectors using moldable materials. This was done using a tool that contained pre-designed for certain components of moldable materials, which could be further adjusted using 3D-editing software. And because these components were made using moldable materials, they could be further sculpted to comply with the needs of the designer. Another interesting approach is to use snap connectors to connect the components for the social robot [19]. Vandevelde and their team used laser-cut snap connectors, combined with 3D printed model designs to put together their social robot. The snap connector of one component, could, for example, be connected to different components that had the receiving end of the snap connector, allowing for more customization and the ability to quickly make connections or undo connections. Ultimately, they also created a textile suit for the embodiment of the social robot, by sewing textile around the components and together with other textile parts, forming one whole robot. Similar to Ramey, Lapeyre used custom 3D printed parts for the body and limbs of the robot, and then placed them together to form a complete design. This allowed them to place the hardware components in the 3D printed components to be then easily connected. However, this toolkit was based on the ability to create one distinct robot with the pre-designed components.

2.4 Commercial State of the Art

When designing and developing a social robot toolkit, it is also important to also look at the current market for additional inspiration to explore what works and what does not work. By doing so, it is possible to essentially look at the pros and cons of each of the given robotic toolkits, cross reference methods that are effective, and try to avoid the problems that the state of the art examples experienced during their research and development. Because it is difficult to find research papers on each of the commercial robot construction kits, websites containing information regarding the product itself will be explored. From these websites, there will be looked at the construction mechanisms and the components that are contained within.

Inflatibits is a modular soft robotic construction kit that allows for the exploration of pneumatically actuated systems [27]. It consists of parts that are made with a soft material, which can be connected to each other and controlled through tubes as seen in figure 2.

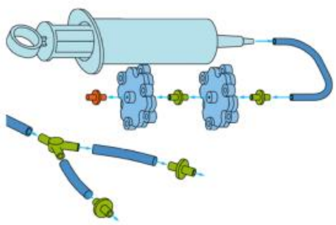

Figure 2: Inflatibits air flow mechanics which can be controlled through Arduino and rigid restrictors.

Due to the soft materials, it is more flexible, which subsequently allows for more compatibility and integration with other construction kits as seen in figure 3.

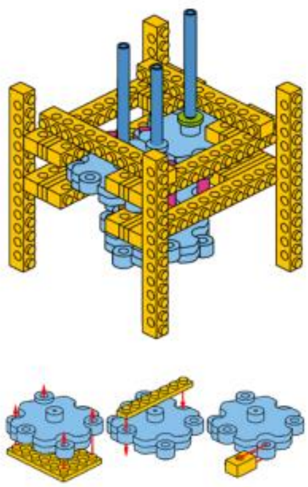

Figure 3: The flexible components (blue) allow it to be connected to other construction materials (yellow).

MOSS is a system of robotic modules that can be connected through magnets [28]. These kits consist of different hardware blocks ranging from distance sensors to microphones to actuators and so forth. At the 8 corners of each block is a groove, which allows a magnet to be slipped in. Subsequently, this magnet allows for connection to other components that also have this magnetic groove, as shown in figure 4. Four magnets cause a

Figure 4: Components used for MOSS robotic construction kit.

solid connection between two components, whereas two components connected through two magnets, would make a hinge and one component connection would create a ball joint. This was done to decrease the learning curve of robot building and allow more people to get some experience building robotics.

mBot Ranger Robot Kit is a 3-in-1 educational robot kit that can be used to build three different models. These are a robot tank, a three-wheeled race car and a self-balancing robot [29]. All of these components can be connected through a combination of holes existing in the building blocks and nuts and bolts. Once the mBot robot is made, it is controllable through the already developed graphical programmer application that can be run on a computer and/or smartphone device, which allows for fast prototyping. computer or smartphone device, as seen in figure 5.

Figure 5: Two designs of the mBot Robot Kit, which are controlled through a smart device.

VEX IQ Robotics are robots that are created using the VEX construction kit [30]. This kit was developed to take "educational robotic to the next level". The toolkit consists of over 800 structural and motion components, 7 sensors, 4 smart motors, and 1 robot brain. Additionally, it also contains the processing components and power source. The components are made of plastic with a lot of holes present in the design. Each of these components can then be connected to other components through small cylindrical shaped snap connectors, as seen in figure 6.

Figure 6: Construction kit components (left) and an example of a designed robot (right).

Fable is an interactive educational robot that allows its users to create different iterations of itself [31]. These could range from making the robot crawl, walk or simply stationary. The system consists of easily connectable components and modules that can be assembled in seconds due to a combination of their connectable shape and magnets. Fable is then programmed through a pre-existing drag and drop application. The edges of certain components consist of parts that are compatible with LEGO blocks [32]. This allows the users to further customize the robot in order to fit their requirements. Components and example final design is seen in figure 7.

Figure 7: Components of the Fable toolkit (left) and an interactive Fable robot created using the toolkit (right).

Vernie The Robot is a social robot constructed using the Boost Creative Toolbox made by LEGO [33]. This toolbox consists of components which can be connected to each other in a similar way that LEGO blocks are connected to one another, as seen in figure 8.

Figure 8: Vernie The Robot with a specific facial expression.

Additionally, there are also sensors and actuators for robot input and output. Because the toolkit is specifically made to be compatible with other LEGO components, users can easily adjust their designs to their ideals if they have additional LEGO blocks. The toolkit is also programmed using a drag-and-drop coding interface which has a low entering threshold. This allows its users to quickly understand the system and start building and programming.

Ultimate 2.0 is a robot construction kit that is used to develop different types of robots [34]. The toolkit consists of individual connecting components that have holes in them. It is these holes within the components that are used to connect them with other components through nuts and bolts, as seen in figure 9.

Figure 9: Possible designs using Ultimate 2.0 construction kit.

Being both compatible with Raspberry Pi and Arduino, it allows a lot of design capabilities. Additionally, the toolkit comes with common sensors and actuators, and blueprints for designing 10 different types of robots to get used to the system.

Humanoid Robot Kit is a toolkit used to develop a robotic agent that can be interacted with and can play e.g. soccer [35]. The components use a "patented joint connection method" to connect to one another and can be easily connected to other components. Additionally, the toolkit provides its users with a programming guide to assist in the development process. The toolkit also contains different input and output components such as the ES smart controller with servo and sensor ports. The final design can be found in figure 10.

Figure 10. Robot created using the Humanoid Robot Kit.

DIY 6-Legs Robot Spider is a robot toolkit made to be combined with Arduino control [36]. The robot has specifically pre-made acrylic designs that are only compatible with other specific parts. These parts are then connected through screws. Additionally, springs are used as a mechanism to assist the movement of the legs. The actuators are encased within plastic bodies which allow them to be connected to the other parts through screws, as seen in figure 11.

Figure 11: Final 6-Legs Robot Spider created using its kit.

BIOLOID Premium Robot Kit is an educational toolkit from which different types of robots can be created, ranging from dinosaurs to humanoid designs [37]. The toolkit includes components such as gyro sensors, smart actuators, DMS and multi-channel wireless controllers. Each of the smart actuators is connected to a custom component, which allows them to be connected to other components through screws. Then this is combined with specific custom components, such as the hands of the robot, upper body, and head, as seen in figure 12.

Figure 12: Humanoid Robots created using the BIOLOID Premium Robot kit.

2.5 Conclusion of Literature Review

2.5.1 Taxonomy and Relevant Characteristics of Social Robots

2.5.1.1 Types of social robots

This review aimed to find what characteristics make a robot effective in personalized social interaction. The literature research has shown that there are different types of social robots, from which there are too many to name. However it is possible to categorize these different types of robots to get a better overview, but the categories depend on taxonomy rules defined by researchers themselves. Some categorize according to tasks, whereas others categorize according to their relationship with humans. There is no general categorization of social robots. Nonetheless, when looking at robotics for personalized social interactions, it is best to focus on their task and primary focus when categorizing them.

2.5.1.2 Outward aspects and presentation of social robots

In addition to this, a majority of researchers mention that people prefer humanoid robotic designs for social interactions. This is because people often associate the looks of the robot with its functionality and since humans socially interact most with other humans, they also have a natural tendency to socially interact more with humanoid designed robots. However, it is very difficult to achieve a full humanoid design, as humans are social experts who will notice the slightest mistakes when not done properly, subsequently leading to a distasteful interaction with the robot due to its appearance (uncanny valley). Additionally, distasteful interactions between humans and robots are observed when humanoid robots are combined with other non-humanoid designs. This is caused by the human tendency to associate Research has also shown that nonhumanoid designs with certain animalistic characteristics and features could work in a social setting.

2.5.1.3 Robot behavior for effective social human-robot interaction

Concerning the behavior of the social robot, research has shown that in the context of social interactions it is important for robots to accurately measure the input it receives from the person and give the appropriate output or reaction. Additionally, research suggests that the robot their ability to think and act autonomously and be trustable would contribute to its acceptance within the context of social interactions. Ultimately these are the important characteristics for making a robot for effective social interactions.

2.5.2 Effective co-design for a social robot toolkit

2.5.2.1 Promoting user engagement in co-design

Because the goal of the project is to use these characteristics combined with robot development to facilitate co-design, another part that requires focus is the facilitation of the co-design. Research has shown that to promote user engagement in co-design, a low skill floor is needed for the users. This means that it should be easy to enter the design process as a user, and they should be able to quickly pick up the basics of robot design. Additionally, from Lee [16] and Thinyane [17] can be observed that social connectedness plays a factor within the users themselves and between the users and the designers. Between the users, this will most likely increase engagement, because they already know each other. Between the user and designer, this social connection allows the designers to better understand the users' needs and that which they are struggling with during the co-design process.

2.5.2.2 Encouraging user creativity

Another important factor is user creativity in co-design. In order to encourage this, research suggests allowing the users to be able to ideate all their possible designs first. Additionally, similar to the previous paragraph, user creativity is encouraged by having a low skill floor. However, it also requires a high skill ceiling. This means it should be easy to start, and if they wish to deepen their knowledge, they should be able to further develop to more advanced designs. Research has also shown that it is important to make it possible for users to easily take steps back during the design process to remove their fear of making mistakes. And finally, research suggests using a semi-structured design process rather than a fully pre-structured design process, because this forces users to also give their creative input in the design.

2.5.3 From characteristics to hardware

2.5.3.1 Components relating to input, output and processing

Within this section different fixed social robots were looked at. More specifically the hardware components researchers used to develop their fixed social robots and how they connected these to create the fully embodied robot. The most common hardware components can be found in table 1 and table 2. These range from touch sensors, cameras, contact sensors, network modules, inertial sensors to LEDs, LCDs, motion actuators and speakers. Additionally, the most used component for processing the input in relation to the output was Arduino. Other projects used Raspberri Pi's. The kind of processor needed largely depends on factors relating to how the final product will be used.

2.5.3.2 Combining the components for an embodiment of the social robot

When looking at the way that these researchers connected their social robot components it was concluded that the most common method was to use 3D printed components.

2.5.4 Commercial State of the Art

When looking at practical examples of existing robot toolkits, it appeared that the most common method used within toolkits was to develop a component that can be connected to the hardware components that subsequently allows it to be connected to other components. The designs that required less input from the users, used screws as a method of connecting the components whereas the less fixed, more creative, designs used nuts and bolts as the most common method. A large number of the construction kits were also compatible with LEGO since it is already an existing construction tool that a majority of the users have access to. This allows them to even further test out their designs of the robot. It was also concluded that a majority of the robots being developed using these construction kits also came with their simplified application for programming the component behaviors of the robot. This lowered the skill floor for the users, allowing them to easily start building and prototyping with the robots.

2.5.5 Indications for next project phase

The knowledge gained from the state of the art review and literature review can be used as a foundation and guideline for the continuation of the project. All the points made in the sub conclusions will be taken into consideration when designing the toolkit. These points are:

- There are a lot different types of social robots.
- Both humanoid or nonhumanoid designs could work for social interactions.
- Robots giving appropriate feedback (timing, realistic answer, expression, action).
- Removal of barriers increases effective co-design (e.g. low entry-level, socialness).
- Creativity using toolkits is caused by it having a high skill ceiling (can develop technologically).
- Social robots sometimes can have recurring components, these can be placed in the toolkit to enable the users to build generic social robots.
- 3D printed components often used for prototype.
- Scaffolding mechanism for prototype construction and easy to use mechanism.

3 Method & Realization

3.1 Approach

This section elaborates on the techniques and strategies that will be used in the development of the social robot toolkit. A general overview of the process that will be taken in order to answer the main research question of this research can be seen in figure 13. The entire of the development and evaluation of the toolkit can be divided into a different set of phases being; (1) Ideation, (2) Specification, (3) Realization, (4) Feedback and (5) Reiteration.

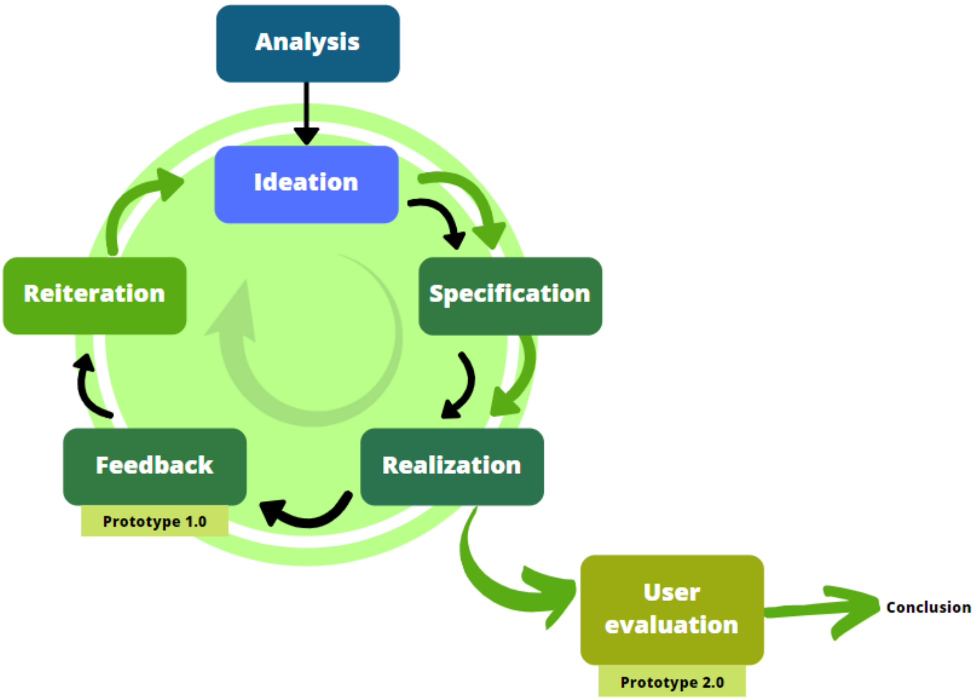

Figure 13: The prototype research process. Inspired by the Interaction Design Foundation [38].

The process describes the use of findings made in the analysis as a starting point for the development of the first prototype of the social robot toolkit. They will be used as a foundation during the next phase, which is the ideation. During this phase, I will think of different scenarios where the social robot toolkit would be used. Note that these scenarios are partially based on or influenced by the examples from the analysis. After looking at the scenarios, they will be placed on one big mind map. Subsequently, additional brief use case scenarios will be thought of and added to the map to find correlations and similarities in the usages. This allows for a more general and abstract view of the purpose of the toolkit, which is needed for defining the expected requirements that will be in the next phase, which is the specification. During this phase, I will properly list out the requirements and look at how they can be realized. Afterward, the realization phase will start. Here the development and use of the components and hardware will be described and how they ultimately form the first prototype of the toolkit together. Afterward, this initial version of the prototype will go through a brief concept and requirements feedback session with stakeholders regarding. The feedback received will be analyzed and taken into account during the reiteration phase of the toolkit. During this phase, the second version of the toolkit will be developed that will be used in the user evaluation tests, from which conclusions can be drawn regarding the research topic.

3.2 Ideation

This section focuses on the creative process of coming up with, developing, and connecting different ideas. Firstly, three possible use case scenarios of the social robot toolkit will be thought of. For these use cases, fictional characters will be described that will need to use the toolkit in practical contexts. From these examples a mind map will be created, which will then be analyzed to produce a list of requirements. It is important to note that the supervisor of this project, who has experience in the field of HRI and social robots indirectly assisted in coming up with the possible use case scenarios by giving brief examples during research meetings.

3.2.1 Use case scenarios

This section will explore three possible use case scenarios of the social robot toolkit. Each part will then describe the story of a fictional character that would have to use the toolkit for their own situated reason.

3.2.1.1 Use case 1

Peter is in his first year of the bachelor program Creative Technology at the University of Twente. During the first two modules of the year he learned the basics of programming and has had a view courses in electronics and circuitry. For the third module he is tasked to work with a company called Friends4All. This company focuses on finding new ways to implement technology so that it can help children with autism develop and improve their social skills. After doing some research, Peter discovers that Social Robots can assist children in improving their social skills. So he decides to create a Social Robot for the company. However, Peter only has a basic knowledge of electronics and does not have a degree in Robotics and Mechatronics. He tries to find a more accessible way to develop the social robot. He is recommended trying out the Social Robot Toolkit by one of his professors at the university. He is given the toolkit and decides to try it out. He wants to develop his social robot together with some of the kids in order to assure that the robot fits their needs. This leads to him using a co-design approach while designing the robot. However, he first wants to make sure that he understands the toolkit before using it in a co-design session with the children. After spending a week of prototyping with the toolkit, he brings an example robot for the children to see what they think of it. A majority of the children prefer a bigger head on the social robot. Since the re-building can be done by multiple people, he asks the children to assist him in constructing the new head. However, the children have difficulties in constructing the head of the robot. This leads to them becoming frustrated during the design process. As a result of this frustration, they start focusing on when the session will end rather than providing as much feedback to Peter as possible. Peter senses this frustration and decided to end the co-design session. He is made adjustments to the head component of the prototype himself, but is now unsure if he might have missed an important feature in the prototype, and is afraid to approach the group of children again for an additional session.

3.2.1.2 Use case 2

Mary-Jane works caregiver for the elderly at the care center. The management at the care center discovers that a lot of the elderly people often take their medication incorrect as a result of not being able to read the small texts on all the different prescriptions. They then ask Mary-Jane to come up with a solution that can solve this problem that the elderly have. She comes up with the idea of a social robot that is able to call elderly people for their medication and give it to them. She wants to realize this idea, however, she has no engineering background so she thinks that it is very difficult. She decides to go online to see what her options are. On a website she finds the social robot toolkit and decides to buy it after seeing that it is recommended for entry-level users. She spends a month testing with the components and trying to understand how the programming code works from the toolkits examples. Afterwards, she makes her first prototype of the toolkit and decides to ask some of the elderly at the care center what they think of her first version of the robot. Her first prototype used facial recognition as an identifier of the person, then looks at the time to decide whether the person is in need of their medication. The elderly people mentioned that they do not like the idea of the robot constantly staring at them for identification as they found it “creepy”. On the spot, Mary-Jane decides to replace the camera with a PIR sensor from the toolkit, and adds a touch screen on the chest of the robot so that people could fill in their identification and receive their medication. The elderly loved this new design and appreciate their new companion at the care center. After a few months of observing the interaction between the elderly and the prototype, Mary-Jane and the management team decide to let develop a fully fledged version of the prototype.

3.2.1.3 Use case 3

Ben works at the museum of Enschede as the buildings tech support. Him and his colleagues find the sphere of the museum dull and decide to come up with ways to brighten the overall mood during the day. He decides that building a robot that greets people and tells funny jokes throughout the day would be able brighten up the sphere in the building. He decides to go online and finds the social robot toolkit. He has some experience with programming, but has not done it in a while and is hesitant at buying the toolkit. In the end he decides to buy it anyway as the toolkit seemed very inexpensive compared to the others on the market. He opens it up and looks at all of the components. He follows the instructions of the toolkit and is now able to find example codes on the website, which allow him to understand the components and their features even more! He is astounded by how easy it was to refresh his memory. He and his colleagues come together and start prototyping with the toolkit. Even the more non-technical colleagues participating in the design are amazed at how easy it is to understand each of the components. Some that refuse to dive into the electronics and technicality are still happy that they are able to be productive, as they can put their attention in constructing the shape of the greeting social robot. They ultimately come up with a robot that can look at people and greet them. Additionally the robot might tell people a joke randomly. One of Ben his colleagues asks if it is possible to add a QR scanner to the robot, so that people entering could scan their tickets immediately at the robot. Everyone agrees that it is an amazing idea. However, Ben knows that there is no QR scanner in the toolkit. However he's able to find QR scanning components online that are compatible with the toolkit of his. After looking ordering the new component and looking at the documentation, he finds a way to connect it to the robot and make it work. The workers at the museum spend the following day observing the interaction between the visitors and the simple prototype of the robot. Throughout the coming weeks the constantly make quick adjustments to the design of the simple social robot until they find a prototype that a majority of museum workers and visitors like. After having made this prototype and testing its features with users, they decide to ask the museum to invest in the development of a fully polished version of the prototype. Everyone is happy with their new friend at the museum and the ambience has increased ever so slightly.

3.2.2 Mind mapping

This chapter focuses on placing the previous possible use case scenarios onto a mind map, then coming up with additional short examples of the social robot toolkit usage. By placing all of these on a general mind map, it is possible to find similarities, correlations, and recurring features. This is done in order to be able to view the purpose and role of the social robot toolkit from a more general and abstract perspective when “zooming out”, which will lead to better defining the requirements. This mind map can be seen in figure 14.

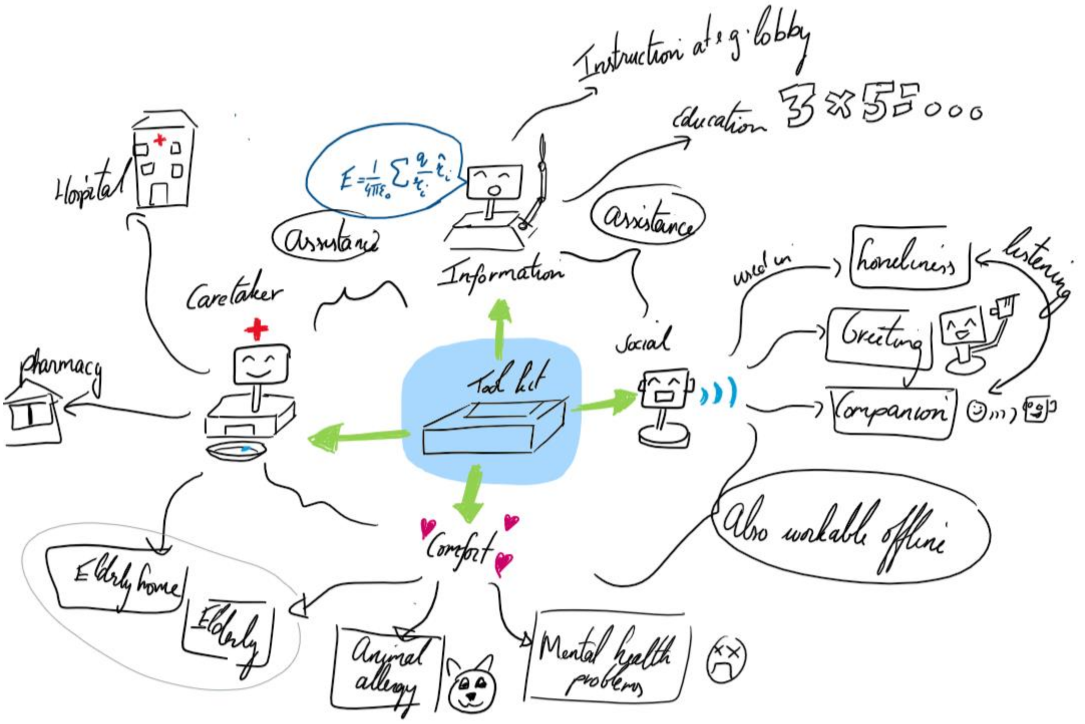

Figure 14: Mind map of the usage of the social robot toolkit. Use case scenarios included with some additional use scenarios.

3.2.3 Conclusion

Similar to what was found in the conclusion of the analysis, the mind map also shows that the social robots that will developed with the toolkit should have the capability of interacting with their users. In most cases this is done by expression through movement or sound. A lot of the usage scenarios showed that it is important for the robot to be able to function even when not connected to the internet. This can lead to limitations in functionality, however can lead to a more reliable robot, rather than one that simply stops working as soon as there is an internet outage. Viewing the mind map from an abstract point of view, it seems that the functionality of the robots can vary greatly. This means that the toolkit should be made in a way that it provides developers with a variety of basic options from which they can choose which ones to use. However it also indicates that developers should be able to further add their personal required features to the pre-existing prototype of the social robot. Additionally, when looking at the steps that each of the toolkit users went through, it is observed that a lot of these have a very similar methodology. The steps taken in this process can be seen in figure 15. Note that this process was partially inspired by the co-design methodology described by E. Marcal [39].

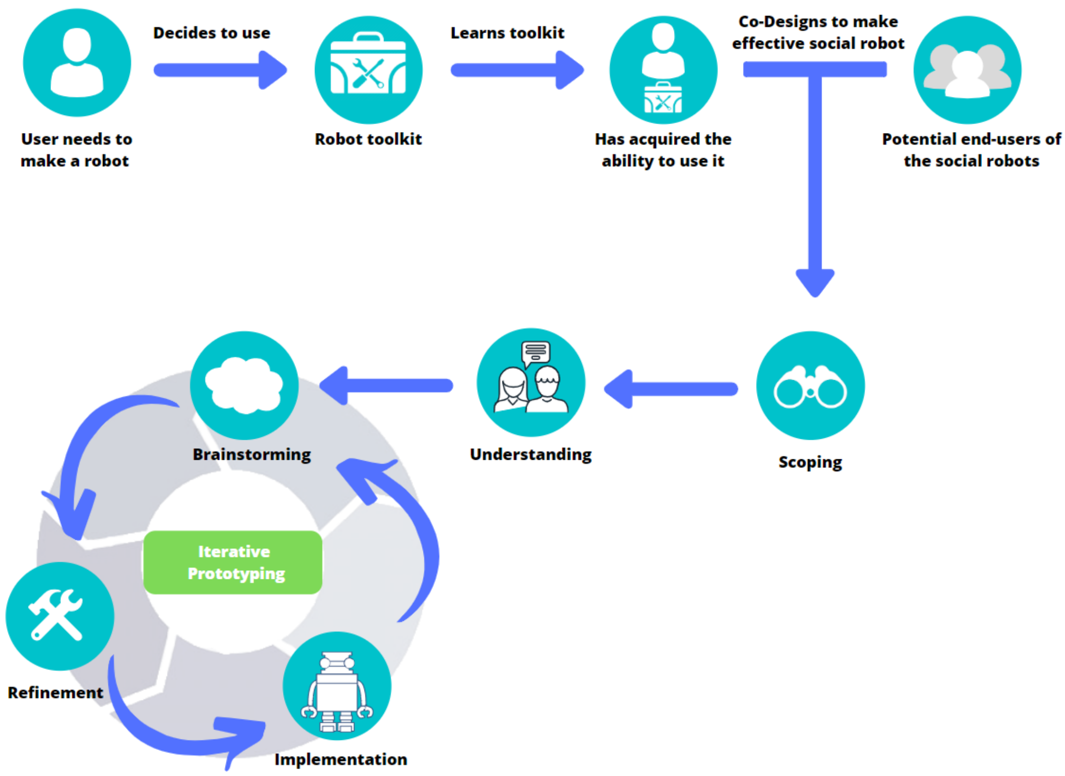

Figure 15: Recurring steps taken by the users when using the toolkit and prototyping with it.

When looking at the process described in figure 15, it is possible to identify at which points in the process the toolkit plays the biggest roles. When analyzing the different steps, the toolkit seems to have the most essential roles in the very beginning, where the user has to learn and decide whether to use the social robot toolkit or not and at the final stage of the toolkit usage, where it is used for iterative prototyping.

In the first major interaction between the developers and the toolkit, they go through the process of learning about the toolkit, its features and possibilities. When looking at the use case scenarios, it seems that people technical and non-technical backgrounds should be able to learn the toolkit. This indicates that getting started with using the toolkit should not be too difficult, because if it were too difficult, the users with a non-technical background will most likely be overwhelmed by the complexity and opt for an alternative.

The second major interaction between the developers and the toolkit is during the co-design usage. The use case scenarios and mind map showed a great importance for the ability to rapidly adjust the social robot prototypes created using the toolkit. This is required, because during co-design sessions, developers only have a limited time to get feedback from the co-design participants and they want as much feedback as possible. This indicates that the social robot developers should be to adjust the design and features of robot according to the feedback of the co-design participant as fast as possible, in order to get additional feedback as fast as possible. Additionally, the use case scenarios also showed a possible relevance for not only the HRI-developer, but also the participants to be able to assist in making adjustments to the prototype. This would be done in order to keep the co-design participants engaged in the project.

Now that the purpose and role of the toolkit is clearly defined, it can be translated into a list of specified requirements.

3.3 Specification & Requirements

This section of the report will focus on developing a list of requirements that the social robot toolkit will have from the ideation conclusion. Afterwards, the requirements from this list can be checked off one by one when realizing the first version of the toolkit prototype.

According to the conclusions made in the ideation, the toolkit should:

1) **Be easy to start off with for the users**. With this is meant that the user should have a general understanding of the social robot toolkit prototype. The user should be able to use some of the components within the toolkit after interacting with it for around an hour. Within this time frame, the user should be able to determine whether they find the usage easy enough to continue using it. This can be broken down into additional terms:
    a) In terms of understanding the features.
        i) How to set the components up (understanding how to properly connect components to each other, measured through observation or interview).
        ii) Understanding the component features and capabilities (being able to understand what the components do, measured through observation or interview).
    b) In terms of adjusting the features.
        i) Programming/reprogramming the components (determining the behavior of the components, user is able to efficiently start programming the components and get it working within a short time frame, measured through observation or interview).

c) In terms of connecting the components.

   i) Connection mechanism should be easily understandable (understanding how to connect multiple components to each other, ideally as soon as interacting with it, measured through observation or interview).

2) **Provide different features and ways to interact with others.** With this is meant that the user of the social robot toolkit should be able to create a basic version of their desired robot prototype. These main basic features were retrieved from the analysis (examples) and can be divided into the following:

   a) Features for expression.

      i) Through movement, or sound (components should physically act, measured through observation or interview).

   b) Features for observation.

      i) Sight and hearing. (components should be able to properly measure external input, measured through observation or interview)

   c) Features for data processing.

      i) How input is translated into proper output (components should be able to process the relation between input and output within a timeframe that is reasonable according to the user, measured through observation or interview)

   d) In terms of being modified to fit specific requirements by end-user.

      i) Adding components to the design that are were not available in the initial version of the toolkit, measured through research, observation or interview)

3) **Be effective in rapid prototyping** (during the iterative design process) in co-design. With this is meant that the user should be able to construct a social robot prototype withing a reasonable timeframe. Do note that “a reasonable timeframe” can differ per person. The estimation given below is what I would consider reasonable. These can further be divided into several sub-categories:

   a) In terms of building the initial version of the desired prototype. (~2 hours)

      i) In terms of construction speed.

      ii) In terms of construction ease.

b) In terms of adjusting the prototype. (~15 minutes)
    i) Removing/adding components in terms of speed
    ii) Removing/adding components in terms of ease

3.4 Realization

This section of the report focuses on the design process and implementation of the social robot toolkit. The second part will focus on the hardware components that will be used to meet the requirements. Afterward, the second part focuses on the ways to facilitate the construction method used for the social robot toolkit. Lastly, the final section will focus on combining these into the first physical version of the prototype, which will be used in the first feedback session. The realization has been further divided into three sub-sections. The first sub-section will discuss the realization of the hardware components, the second sub-section will discuss the realization of the construction mechanism. This focuses on how the components will be connected to each other. The third and final sub-section will discuss the combination of the first and second sections into the first version of the social robot toolkit.

3.4.1 Hardware feature components

The following sections describe several ways of tackling the requirements in terms of input, output, and processing.

3.4.1.1 Main controller (processing & thinking)

According to requirements 1 and 2, the components within the toolkit should be easy to understand and start using. A good solution for tackling these requirements would be the use of Arduino as the main controller for the toolkit and its components [40]. This is because Arduino is an open-source platform for building electronics that has a low entry-level for the beginners but still provides the ability to make complex installations for the more experienced. Additionally, it comes with a large active community online, that can provide information and assistance for the problems the users are encountering. This information can range from troubleshooting forums to example projects that others have made. Thus, for the toolkit, it will be decided that Arduino Unos will be used as the main controller board. However, because one single Arduino has a limited amount of output, an additional Arduino will be added to the toolkit, along with an Arduino Mega.

3.4.1.2 Hardware feature connection method

However, most Arduino projects also require the user to either use breadboards for construction or soldering. Building circuitry through breadboards and having to solder components together are the opposite of requirement 3, as they are not fast and efficient enough. A solution for this is to use a Grove System for the toolkit [41]. A Grove system is an interchangeable, standardized connector system that is built for prototyping. Its main component, the grove shield, is compatible with both Arduino Unos and Arduino Megas. Compared to using breadboards and soldering cables together, components from the Grove system are built in a way that allows them to only be connected in a certain way, but the way that they are connected to each other they use plugins. This connection method can be seen in figure 16.

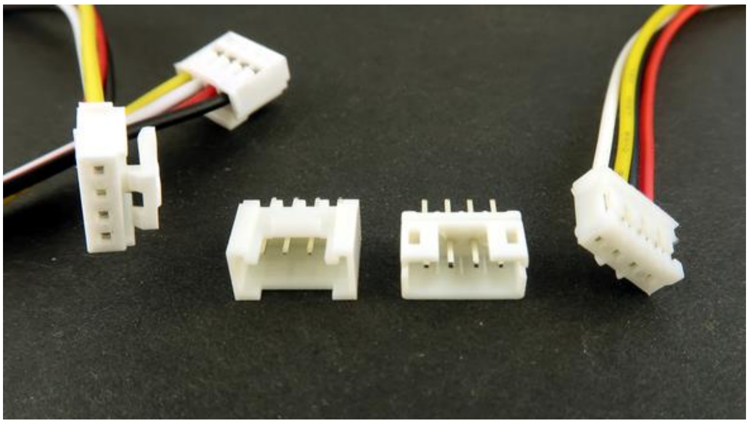

Figure 16: Image showing the connection method used for the feature components of the toolkit.

The main "bridge" between the feature components and the Arduino will be the Arduino Grove Shield V2.0. After plugging this unto an Arduino, it provides a simple way of connecting the controller to its feature components. This board connected to an Arduino can be seen in figure 17.

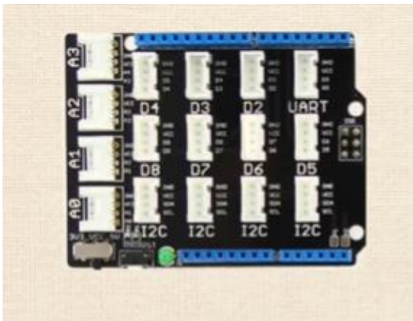

Figure 17: Grove base shield V2.0 showing the easy 4 pin connectors that will facilitate rapid prototyping.

According to requirements 2, the social robot prototype made using the toolkit should be able to interact with the end-users in different ways. It is very difficult to create a prototyping toolkit from which the users can build their ideal social robots because there are countless ways that social robots, and thus countless different components that can be used to add features. Additionally, Seeedstudio has developed more than 300 different Grove Modules and it would be quite overwhelming, expensive, and unnecessary to include all of these components in the toolkit. However, it is possible to look at the hypothetical use case scenarios, and try to identify the most basic requirements that will be needed to start prototyping with the toolkit. These components will then be placed into the toolkit as a start. After trying the toolkit and its components out and understanding how it works, the user will always have the option to add their own required components as Arduino is compatible with a lot of different additional modules.

3.4.1.3 Observation components: Computer vision

When looking at the toolkit prototypes from both use case scenarios and mind map, it can be seen that the social robots are often required to identify those they are interacting with. These can be done through facial recognition. Additionally, the mind map also showed that there is an importance in the ability to work offline, and the conclusion from the analysis showed that it is important for the social robot to be able to give feedback on time. B. van Manen already did a building block comparison in their bachelor thesis to determine which component would be best given the circumstances [42]. This component comparison was done in a table and compared e.g. communication protocol, online/offline/, programming environment features. Ultimately they concluded that the best component (given the similar requirements) would be OpenMV Cam H7. This component can be seen in figure 18.

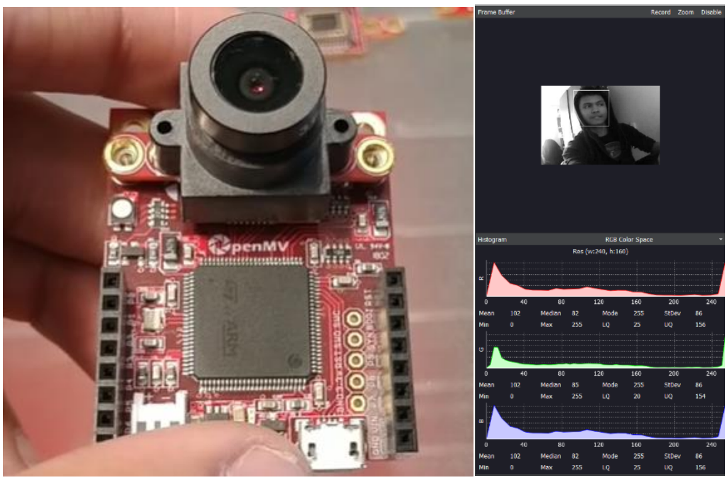

Figure 18: OpenMV Cam H7 (left) and OpenMV face tracking example (right).

This camera is not a Grove component, however, it is a powerful image recognition and tracking module, which is capable of working without the internet and is compatible with Arduino. It comes with its own free to download programmable interface. Additionally, it provides users with a lot of examples, which users could use as a guiding tool for understanding the component. This is why this component was chosen to be included as the computer vision component of the toolkit. It is important to note that this component comes with its own IDE called OpenMV IDE (seen in the right image, figure 18). Additional component information and documentation can be found in the components documentation [43].

3.4.1.4 Observation components: Speech synthesis and recognition

Another recurring feature from the mind map and use case scenarios that would be needed to make a prototype using the toolkit is the ability to recognize vocal commands, and provide be able to give some form of audio feedback back to their users. A Grove Module that could be used for this is the Grove – SpeechRecognizer. This module comes with built a built-in speech recognizer that is able to recognize a set of pre-specified commands (22). This comes with both its own advantages and disadvantages. This is said because ease of use is added to the toolkit at the cost of customizability. However, there are still a lot of simple social robot applications that can be created using the toolkit. The Grove SpeechRecognizer module can be seen in figure 19.

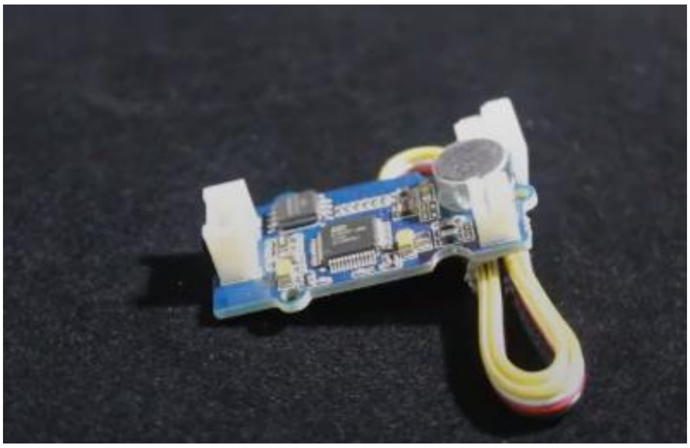

Figure 19: Grove SpeechRecognizer with Grove 4pin attachment.

3.4.1.4 Expression components: Audio Output

The Grove SpeechRecognizer is used for voice recognition, however, for the examples from the mind map, it appears that it might also be important for the social robot prototypes made using the toolkit to be able to output audio. A component that could be used to realize this is the Grove -MP3 v2.0. This is an audio module that is compatible with the Grove Shield allows users to play WAV, MP3, and WMV formats. The shield also comes with a built-in SD card reader, which would allow the user to use their own WAV/MP3/WMV files, which the robot would be able to use. Note that any speaker with an audio jack and power can then be connected to this module in order to play audio files. This component can be seen in figure 20.

Figure 20: Grove- MP3 v2.0 component used for Audio output.

3.4.1.5 Advanced speech recognition and synthesizer

In case the user of the social robot toolkit would want to make custom voice commands (recognition and synthesis), another module would need to be used. This module is comprehensible and relatively simple speech recognition and speech synthesizer and is called the MOVI shield. It can recognize certain voice commands and play certain audio commands. This would be ideal for a robot that has to interact with a lot more vocal commands. Additionally, this comes as a pluggable shield, which is compatible with Arduino Unos and Arduino Megas and is useable offline and would function as a medium for both audio input and output. It is important to note that this shield is also directly programmable through the Arduino IDE, which simplifies the implementation process. An image of the MOVI shield can be seen in figure 21.

Figure 21: Movie shield that can function be used for custom voice commands.

3.4.1.6 Expression components: Miniature and slightly larger scale

Additionally, from the examples encountered in the analysis and use case exploration appeared that social robots are required to also be able to move, which would allow the robot to move their body parts such as the neck, or allow the robot to give visible expressions for example eyebrows. Simple components that can be used to implement this are Servos, which are simple to control and allow the easily control of small movements. Two different servos that were added; a smaller more common SG90 servos for the movements of smaller components that do not carry a lot of weight, and a larger HK15138 high torque analog servo, to deal with the movement of larger, heavier components of the social robots. These two servos can be seen in figure 22 on the next page.

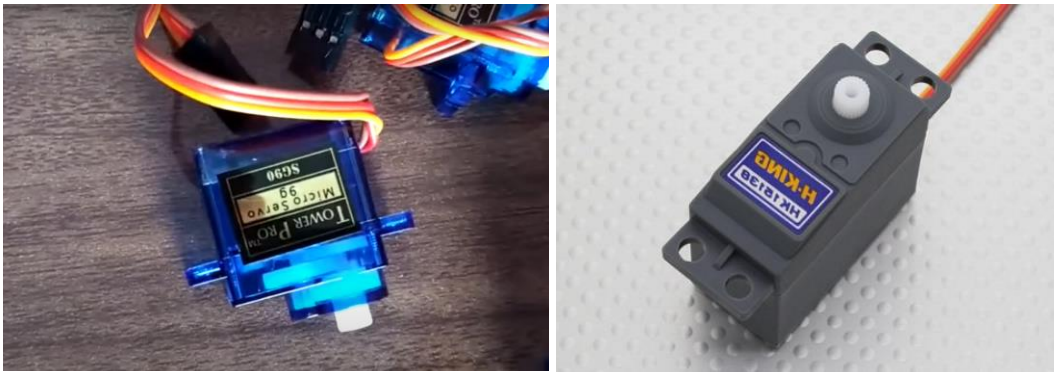

Figure 22: Left image showing the smaller SG90 servo, right image showing the larger HK15138 servo.

3.4.1.7 Expression components: Possible eyes or other form of expression indicator

Similar to how smaller servos are used as a way for the social robot prototype to express itself, examples from the state of the art also indicated a large prevalence for the social robots having eyes. This can be achieved through different ways, however, because one of the user requirements is that it needs to be as user friendly as possible, a Grove LED matrix can be used. These Grove LED matrices are simple programmable 8*8 matrices, and come with their own shield. This means that they can easily be connected to the Grove System, and could be used by the HRI-developers as the eyes of the robot. Which would allow the robot to more accurately express their emotion. This LED matrix can be seen below.

*Figure 23: Grove LED 8*8 matrix, with built in shield. Left image showing the individual LED's forming a heard together. Right image showing what the component looks like off.*

3.4.1.8 Observing components: Computer object detection

For observing, the example social robots from the analysis and ideation phase also showed a relevance for detecting users without having the robots recognize the users. This was mainly due to people having issues related to their privacy being invaded. This is where a Grove PIR (passive infrared) motion sensor comes in. This grove component can be easily connected to the Grove system and would allow the prototype to detect motion. Additionally, this sensor would be able to provide the social prototype with the ability detect any object within a certain range, which allows for example, navigation features. Image of the grove PIR sensor can be found in figure 24.

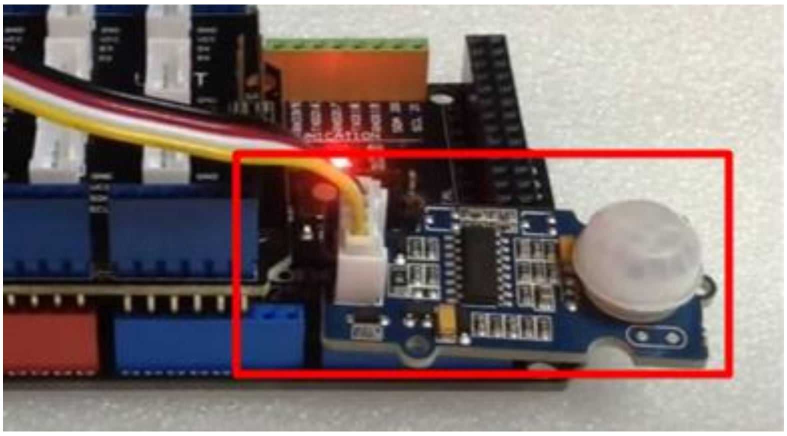

Figure 24: Grove PIR sensor (in the red square) connected to the Grove Shield.

3.4.1.10 Observing components: Touch recognition

The examples from the state of the art and mind map, showed that the social robot prototypes sometimes also require interaction through touch. This can be implemented using a Grove Touch sensor system. These touch sensors detect the change in capacity whenever an certain object is near, for example a finger. Seeedstudio has two different touch sensors, both will be included in the toolkit to provide the user with the choice of picking whichever one fits their needs better. These touch sensors would allow the prototypes of the social robot to detect whether they were being touched and where, in order to give the appropriate feedback. These touch sensors can be seen in figure 25.

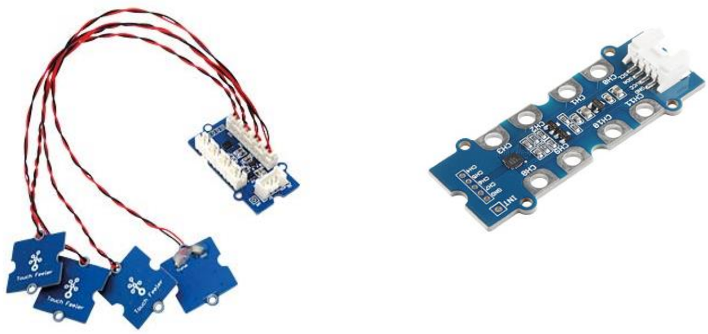

Figure 25: Grove Capacitive Touch Sensors. The left image shows the a touch module to connected to 4 grove capacitive touch sensors. The right image shows the 12 key capacitive touch sensor, which would allow the user to connect their own custom capacitive touch sensors.

3.4.1.11 Expression & Observing components: General display & touch screen

When looking at one of the use case scenarios (the second one), and some of the expression components used in the examples in the literature review [26], relevance for a display was shown. This display would then form as a means of expression for the social robot. Because touch also seemed to be relevant for social robots, these two major aspects can be combined into one component; an LCD touch screen. This is why the TFT LCD screen module was added to the toolkit. This mini-touch screen would allow the HRI-developer to use it as either a way to display the robot's face or as a menu from which the user could give their input. Note that this module is not a Grove System module, however it comes with a built-in shield, that can directly be placed on top of Arduino UNO and Arduino MEGAs.

Figure 26: Two images showing the TFT LCD screen module from two different angles.

3.4.1.12 Expression component: vibration

Some of the possible prototypes from the mind map that had to be used in a context of social care, indicated that relevance for the ability to vibrate. Similar to how animals and humans give a certain feeling when touching them, social robot prototypes should also be able to do so if needed. This feature or ability to vibrate can be implemented using a Grove Vibration Motor. It consists of an integrated is a coin-shaped DC motor, that vibrates when the input signal is logically HIGH. It is very easy to use and compatible with the Grove system. An image of the Grove Sensor can be seen in figure 27. Using this module, HRI-developers would be able to use the toolkit to create a “more realistic” feeling when touching the social robot.

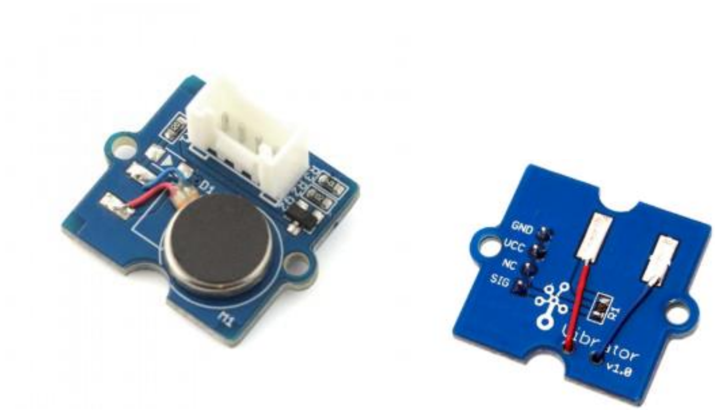

Figure 27: Grove Vibration Motor. The left one shows the top view, whereas the right one shows the bottom view.

3.4.2 Connecting Components

This section will describe the construction mechanisms used to combine the previously mentioned hardware components into a prototype. Additionally, it mentions a main possible power source that the toolkit developer would be able to use. Then finally, the developed components will be compared to the existing construction mechanism in order to make clear why it is unique.

3.4.2.1 Construction mechanism

According to the requirements (3a, 3b 1c), the components should be easily understandable and facilitate rapid construction. Additionally, a wide variety of designs should be able to be constructed using these components, offering the toolkit users enough room for customization when prototyping. A solution that could tackle these requirements is the use of a mechanism that uses nuts and bolts to connect different parts containing holes to each other, inspired by the concept of a multi-model engineering set [44]. The use of nuts and bolts to connect components that have holes in them would be very easy to understand for those with any form of common sense, as similar product usages are taught from kindergarten [45]. A different set of components were modeled in SolidWorks and tested. The initial 3D-models had problems relating to the spacing between the holes through which the bolts had to go through and problems in the distance between the holes causing an inability to place components next to each other. This lead to the 3D models needing to be redesigned, from which the process and usage can be seen in figure 28.

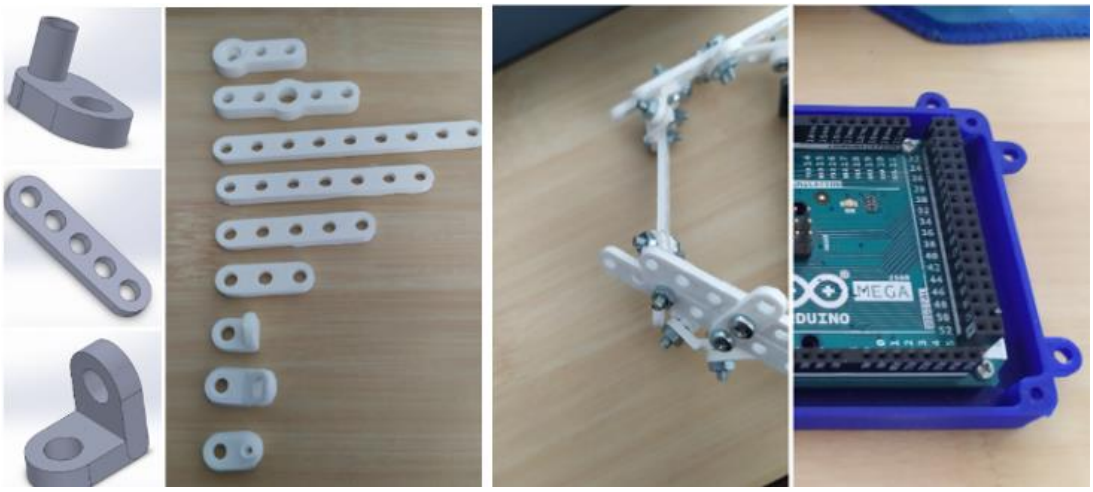

Figure 28: Examples of the components that wil be used to construct prototypes using the social robot toolkit. The first image (from the left), shows only a few of the examples of the models made in solidworks. The second image (from the left) shows some of the components after being 3D printed. The third image (from the left) shows how nuts and bolts can be combined with these components in order to construct custom. The fourth image (from the left) shows how a hardware component that was combined with the 3D models to allow for the connection of the smaller components.

Briefly described, there are linear connector components ranging from 3 holes, to 5 holes, to 7 holes to 9 holes. Smaller components can be used to connect parts across smaller distances, whereas the larger ones could be used to bridge the gap between larger distances between components. Aditionally angled componenets were added. One allows for a 90 degree rotation of construction, whereas the other allows for a 135 degree rotation. The servos also received their custom 3D modeled and printed connector component. Lastly, “small to large” components were added so that some of the hardware components could be connected to something that allows them to be connected to other connector components.

3.4.2.2 Foundation & Power Source

All of the toolkit constructions will require to be powered at some point. This is why a separate 3D case was developed for the powerbank of the toolkit. Which was important, as the powerbank can be used as a base in a lot of different constructions due to its weight. This base model went through two different itterations as the first model had issues with securely fitting the power source within itself. This can be seen in figure 29.

Figure 29: Models of the power bank base. The fist version on the left showing how it had to be cut open and melted to make the power bank securely fit inside of it. The second version on the right showing it it securely fitting and holding the powerbank in place, while also function as a base for the addition of other components.

All of the larger components also received their own custom 3D model. These were the Arduino Uno's, the Arduino Megas, and the heads of the servos. This was done in order to add to the stability of the toolkit constructions. An example can be seen in figure 30 on the next page.

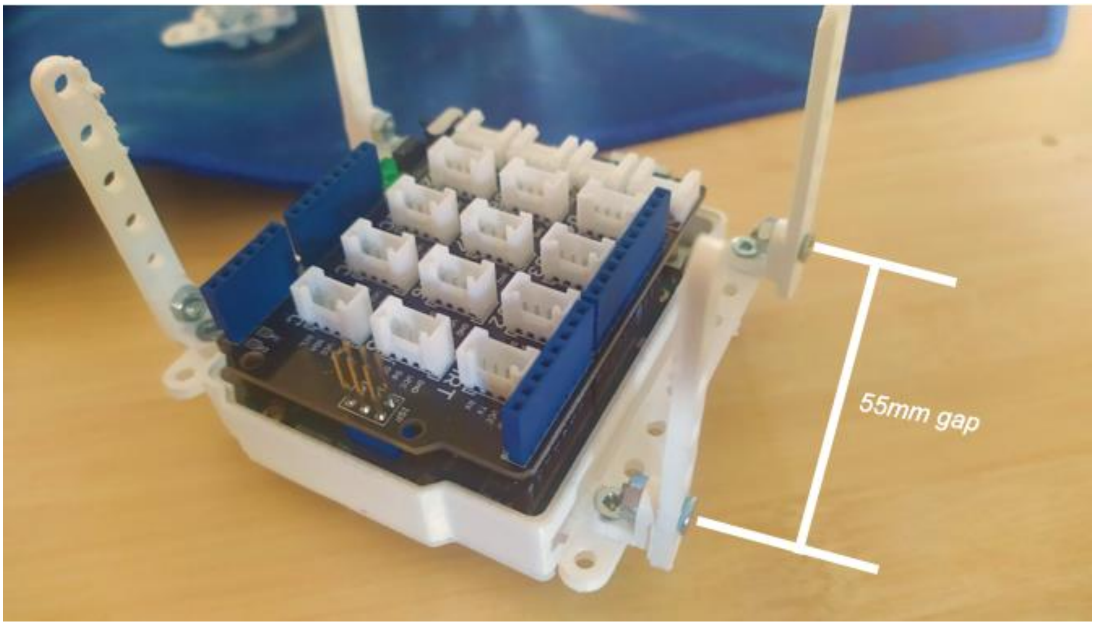

Figure 30: Image showing a custom model connected to the Arduino, which could then be connected to another part using some of the connector components, nuts and bolts.

3.4.2.3 Uniqueness of construction mechanism

One might compare these connection components to the multi-model engineering set [44] it was inspired by, or the very popular Meccano construction sets [46] and wonder why these construction sets were not used as a connection mechanism. It is true that these are very similar, especially since the design was partially inspired by one of the existing products, however, the problem with these products is that they are specifically built to be effective in the construction of a pre-determined model (e.g. a racecar, or a truck), whereas the developed connection mechanism is specifically designed to provide the user with a wide range of possible constructions, rather than point them in a certain way. Furthermore, when buying a mechano set, only specific components could be used for constructing a custom robot, and the rest of the components would have no use, as they are specifically made to build a certain construction and have difficulties being applied in other constructions. Additionally, Meccano uses their own measurement for between the holes depending on the final product construct, whereas the length and distance between holes of developed connection components and mechanism was built with specific use for Arduino in mind. For example, the holes in the 9 hole connector component can perfectly fit on the base model of the Arduino in terms of its outer connection holes. This is possible due to the centers of the holes of the two components being perfectly distanced from each other (55mm, see figure 30). Consequently it then also contributes to the overall stability of the design. If the component was not perfectly built in this way, at least two components would be needed to bridge the gap if needed. Because two components that are connected to each other are used rather than one, it will in most cases be less stable.

Another unique and important feature of the developed connector components, is that they were specifically built to be able to place multiple of the linear connectors parallel in holes next to each other on top or below a common non-paralleled linear connector piece. This would is applicable to both the holes at the edges as well as those at the center. By doing this, the toolkit user would be able to make a more "closed" design if they wished to, by placing multiple of the linear connectors next to each other on a common orthogonal linear piece. Note that with "closed" design is meant a construction design that is meant to be seen as one single whole design, rather than a see-through design. All of the examples from the Commercial State of the Art all facilitated this "closed" design, which indicates a relevance for this option to be available to the user. The problem with Meccano sets is that they do not always allow multiple connector pieces to be connected next to each other on one common piece. An example of this can be seen in their Meccano 5-in-1 motorcycle set [47]. The multi-model engineering set [44] does provide users with this important option, however, their mechanism consists of thin metal linear components with holes. From personal experience and knowing metal components will rust over time [48], this specific construction set was not used either as the rust may discourage users from touching the components. Another possible downside of using thin metal as a construction method can be caused by their inflexibility. The PLA used for these connection components can be for example stretched out by the user or indented using the bolts and nuts. An example of this is if I wanted to construct one long arm where the end of one linear construction component is connected to the end of another linear construction component using max 2 bolts for per component connecting. During construction it would seem that at some point the metal components would be less break down as a result of it being heavier (metal instead of PLA) and less stable (inability to fully tighten nuts and bolts tightly within hole).

Another well-known construction mechanism that the developed mechanism can be compared to is LEGO [32]. This would also be a viable option to use as the main construction mechanism. However, when looking at LEGO designs, they often do not facilitate the management of cables properly. This is because LEGO blocks do not have holes in them. As seen in chapter 3.4.1, there will still be cables that need to connect from point A to point B and by using the developed connection mechanism components, the HRI-developer could build it in a way that holes are present in the design for proper cable management. Additionally, LEGO blocks excel at the one-dimensional building. With this is meant that it is good for building in a linear direction (e.g. from bottom to up, or from left to right). However, when looking at the examples from the analysis, social robot prototypes will be required to be built in multiple dimensions. With this is meant that the construction mechanism of the toolkit should provide the user with building from the bottom up, and also facilitate building e.g. left to right or continuing the construction at a certain angle.

It is important to note that these alternative construction mechanisms are not particularly bad, and are still viable construction mechanisms. In the future it might be a good idea to incorporate these within the toolkit.

3.4.3 First version of the toolkit

This section will discus how the components from the previous realization chapters will be combined to form the toolkit. Then, a summary will be given of the solutions found during the realization phase for the requirements they were supposed to tackle. Afterwards the uniqueness of the toolkit will be described by comparing it to existing toolkits.

3.4.3.1 Toolkit 1.0

Together, the components from chapters 3.4.1 and 3.4.2 were combined into one toolkit as seen in figure 31. The connecting components and the hardware components will be placed sorted and placed into their categorized sections. An overview of the categorized sections will be printed and available in the final version of the toolkit. This is done in order to keep an overview of all the components within the toolkit. By keeping an overview, the chances of the user being overwhelmed will be less likely. Additionally, the toolkit will come with instructions on how to find manuals for each of the components. This is done in order to already teach the participants what they will need to do when prototyping hardware, i.e. looking for more information online.

Figure 31: Image showing the social robot toolkit (closed).

Figure 32: Top compartment of toolkit open (not all components present)

Figure 33: Toolkit fully open showing brief descriptions of some of the components present within the toolkit.

As seen in figure 32 and 33, the top compartment facilitates both components relating to construction and hardware feature components. This combination was done in order to still have an aesthetic appeal towards the users who are looking at it while the social robot toolkit while it is closed. By doing so, it is possible allow the user to get a feeling of the possibilities of the toolkit. This resulted in the top left sections (top-left square, figure 33) and top right section (top-right square, figure 33) being used for to display the construction components, and the middle section (top-middle square, figure 33) being used to display some easy to use components. This was done with the purpose of intriguing the user into trying out these components first when starting to use the toolkit. The bottom right section (bottom-right square, figure 33) will be used for all the possible additional cables needed for prototyping. This is because it is a large section that the user can use to "dump" all their additional components. The middle bottom section (middle bottom square, figure 33), will be used for the advanced voice recognition modules and some of the computer vision models. This choice was made in because these components fit perfectly within the squares. The bottom right section (bottom-right square, figure 33), will be used for the components relating to the movement of the prototype.

3.4.3.2 Requirement and solution overview

In order to prove that the social robot toolkit has fulfilled the requirements, the requirements list will be compared to the solutions that to toolkit provides to tackle these requirements. This comparison can be found in table 2.

Table 2: Revisiting requirements.

Requirement	Toolkit solution
1) Be easy to start off with for the users. a) In terms of understanding the features. i) How to set the components up. ii) Understanding the component features and capabilities b) In terms of adjusting the features. i) Programming/reprogramming the components. c) In terms of connecting the components. i) Connection mechanism should be easily understandable.	1) ✓. Be easy to start off with for the users. a) ✓. In terms of understanding the features. i) Quickly pluggable to shields/other components. ii) Name of component present + website information b) ✓. In terms of adjusting the features. i) Comes with a lot of example programs and own IDE. Programs saved in IDE can be adjusted or recovered. c) ✓. In terms of connecting the components. i) Nuts and bolts mechanism is simple. Shields and grove connectors can only be connected a certain way.
2) Provide a variety of different features and ways to interact with others. a) For expression.	2) ✓. Provide a variety of different features and ways to interact with others. a) ✓. For expression.

i) e.g. through movement, or sound. b) For observation. i) e.g. sight and hearing. c) For processing the data (thinking) i) e.g. what to do given a certain input d) In terms of being modified to fit specific requirements by end-user. i) Adding components to the design that are were not available in the initial version of the toolkit.	i) Servos (large and small), Audio output modules (grove and shield), vibration modules (grove), mini display (shield), LED matrix. b) ✓. For observation. i) Camera modules, speech recognition, capacitive touch sensor. c) ✓. For processing the data i) Some modules have on-board processing of information, Arduino Mega and Uno can process part of the information. d) ✓. In terms of being modified to fit specific requirements by end-user. i) Use of Arduino as main microcontroller allows for this.
3) Be effective in rapid prototyping (during the iterative design process) in co-design. a) In terms of building the initial version of the desired prototype. i) In terms of construction speed. ii) In terms of construction ease. b) In terms of adjusting the prototype. i) Removing/adding components in terms of speed ii) Removing/adding components in terms of ease	3) ✓. Be effective in rapid prototyping (during the iterative design process) in co-design. a) ✓. In terms of building the initial version of the desired prototype. i) Connectable nuts and bolts pieces, 4 pin connectors, shield connectors (avoidance soldering, cable excess). ii) Connectable nuts and bolts, Grove 4 pin connectors, shield connectors (avoidance soldering, cable excess).. b) ✓. In terms of adjusting the prototype. i) Connectable nuts and bolts, Grove 4 pin connectors, shield connectors (avoidance soldering, cable excess). ii) Connectable nuts and bolts, Grove 4 pin connectors, shield connectors (avoidance soldering, cable excess).

3.4.3.3 Uniqueness Social Robot Toolkit compared to existing toolkits.

Now that the first version of the social robot toolkit is developed, it is important to also look at how it compares to existing robot construction sets What makes the social robot toolkit unique largely depends on that which it is compared to. For example, compared to most of the examples mentioned in the Commercial State of the Art and Literature review, it is safe to say that this toolkit provides users with the ability to create their own needed social robot prototype, rather than directing the HRI-developer in a certain direction. Most of the construction sets come with the final design on the cover, whereas the social robot construction set does not do so. Additionally, when compared to existing robot construction sets, the social robot toolkit not only comes with the tools needed to make a social robot, they also come with components that would allow for interaction with humans (touch sensors, computer vision, audio recognition, and speech synthesis). Similar to some of the other construction sets, the social robot toolkit uses Arduino boards as main microcontrollers, which allows for further expansion of features, as Arduino is compatible with a large number of different components. It is important to note that the use of large shields can also fully occupy an Arduino UNO. This is why the toolkit comes with different Arduino boards (2x Arduino UNO and 1x Arduino MEGA). Such a large shield, would for example be placed on an Arduino MEGA, from which the leftover pins could be used to communicate with the other Arduino microcontrollers.

3.5 End-user expectations feedback

This section will focus on the initial stakeholder feedback regarding the concept and first prototype of the toolkit. It is important to note that this research is done in June of the year 2020, meaning that it has to comply according to the Covid-19 regulations given by both the Dutch government and University of Twente and EEMCS faculty. A general overview can be found on the website of the Dutch government [49]. In short, any form of user feedback that will have to be acquired without physical human contact, as human contact can increase risk of spreading the possibly lethal virus. How the research will comply with these regulations is explained in the method. Afterwards the results will be noted, from which a conclusion will be drawn. The major points within this conclusion will be used as additional feedback to adjust the toolkit before the user engagement evaluation.

3.5.1 Method & Procedure

The best way to receive formative feedback effectively is to sit down with the participants and ask them in person. However this, is not possible, as it does not comply with the previously mentioned national Covid-19 regulations. The second option is to interview the participants through a video chat. However, since a majority of the participants have to have their meetings and classes through video chat, a distaste has been created for using online video chat [50]. This might result in less formative feedback or them declining participation in the research. Additionally, these participants will already be required to participate in the final toolkit usage evaluation later in the research. Which will already be a relatively long session and is why the first form of user research will be executed through a less stressful and time intensive manner. A research method that complies with these requirements is an online survey.

A survey was created using google forms and has the goal of receiving stakeholder feedback on the prototype. This survey can be sent to the stakeholders through an online medium. These people will first be introduced to the research topic by allowing them to read the research brochure first, which can be found in Appendix 1. Since this is a formative research, a large priority will be placed on quality over quantity. This means that an emphasis will be placed on receiving constructive feedback, rather than on statistical accuracy. Note that the participants are free to ask questions to the researcher while filling in the survey. This will be done either through text or through audio or video call if the participants wished to. The goal of this research is to gather information on the expectations of the users regarding the concept of social robot toolkit and their acceptance rate of the first version of the toolkit. In other words, in the case of the goal, a large emphasis will be placed on gathering actual qualitative feedback, rather than gathering as much possibly less formative feedback. When doing online surveys, it is important to note that the duration of completion should be within a certain amount of time. Research suggests that in order to prevent the decline in the quality of formative feedback, it is better to keep completion of the survey between 15 to 20 minutes [51].

It will be sent out to possible end users, that have experience with prototyping, for example university students with a background in engineering to get input on their expertise. Additionally, this survey will be sent out to those who do not have an engineering background, however, should also be able to prototype using the toolkit, for example those who are working in the care or have experience working in the care with other people. Together, these will give a better overview of the issues, concerns and goals of the first version of the social robot toolkit. Note that the participants will be required to individually fill in their survey to be able to provide their own true, uninfluenced, answers. Additional information regarding the procedure, usage of user data can be found in the information brochure in Appendix 1.

The survey itself has been consists of different phases. The survey will first inform the users about the research project itself. Secondly, it will give the purpose of this research. After informing the survey participant about the survey, they will be asked questions in order to gather formative feedback on their expectations with regards to the concept and initial version of the toolkit. This part of the survey can be broken down into four phases. The first phase will establish the frame of mind of the survey participant. In the second phase, the survey will focus on exploring their expectations of a toolkit for social robot prototyping. Then, third phase will focus on reveal and alignment, meaning the first version of the social robot toolkit will be presented, and the participant will compare their expected version and the social robot prototype version. Afterwards, the final phase focus on building on and exploring these possible differences. The specific questions that will be asked can be found in Appendix 2.

These questions cover the user expectations of a social robot toolkit in terms of:

- Possible usage and interaction
- The types of abilities that the social robot would have
- The ways of construction that can be used
- Importance of using the toolkit in co-design
- How the prototype toolkit differs from their concept

The user consent form can be found in 3.

3.5.2 Results

A total of 6 participants filled in the survey. The age, educational background, and gender varied to ensure the feedback from different types of people. The participants were first asked to place themselves into a scenario where they would be required to build a social robot through co-design and would have to use a toolkit. After placing themselves in the scenario they were asked about whether they would use such a toolkit. All but one mentioned that they would not mind starting off with the toolkit. The expectations of the participants with regards to the social robot toolkit are divided into several different sub paragraphs. These different subjects can be found below.

3.5.2.1 Possible usage and interactions of social robot prototypes

Afterwards, they were asked how they see that the social robot toolkit would interact with the users. A different set of answers was generated by the participants of the survey. The most common nouns were looked at and words that had a similar meaning were grouped. This was done in order to better be able to analyze and present the qualitative data provided by the participants. A majority mentioned use of the constructed prototypes to function as personal assistance social robots for humans. Additionally some of the other recurring usages were time management, assisting people with loneliness, care or assisting those with social problems.

3.5.2.2 Required features of the social robot prototypes

After answering this question, the participants were asked about what abilities they expected the prototypes built using the toolkit to have. A different set of good examples were given. These examples were analyzed, and categorized to be able to analyze them from a more abstract point of view. The most common abilities described by the participants were the ability to observe, in terms of visual and audio ques. Additionally, a lot of the participants also mentioned the ability to express the emotions of the robot were important both vocally and appearance wise. Two of the participants (care background & construction background) also mentioned the importance of the social robot to be able to tailor their behavior and actions toward the person that is using them. For example to be able to know how to cheer that person up, or to be able to learn and understand the person's thought process. Another participant (background in Advanced Technology) particularly mentioned the use of Arduino and "connecting components" to be able to realize these abilities. Half of the other participants mentioned that they find it important that such a social robot prototype should be able to keep time in order to fulfill certain duties such as personal assistance and activity management.

3.5.2.3 Prototype construction mechanism and materials

The research continued by asking the participants what their expectations were with regards to how the components were construction wise. These were both expressed in terms of construction mechanisms and materials used. One of the participants that had a background in construction mentioned the importance of the materials being durable for different environments. They mentioned that the use of metal frame would be vulnerable for corrosion and that certain plastics would be vulnerable for high temperatures. However, another majority of the participants mentioned that they preferred the use of hard plastic as the main construction material of the prototypes. One participant (background Advanced Technology) in particular mentioned the use of partially done parts to avoid having to build completely from scratch. Another (background in care) additionally mentioned a specific construction mechanism not being relevant as long as there is an instruction manual for protype construction.

3.5.2.4 Toolkit relevance in co-design

During co-design, all of the participants mentioned in different forms, that they found the adjustability of the prototypes the most important. Half of the participants additionally mentioned the easy of use and efficiency in which prototypes could be constructed during the co-design sessions. One participant (background in education and design), mentioned that they found it additionally important that also the participants were “enthusiastic” about the prototyping process.

3.5.2.5 How the prototype toolkit differs from their concept

In this part of the survey, the participants were shown first version of the social robot prototyping toolkit, and were asked whether it matched the concept of the toolkit they were expecting. The majority mentioned that it matched their expectations of what such a toolkit should be. The participant with the background in construction mentioned that it was missing wheels, as a robot would be required to go from one place to the other when working “in the field outside”. Another participant mentioned that they did not expect such a toolkit, because they did not think about the toolkit having movement components at all.

3.5.3 Conclusion

All of the possible user interactions were taken into consideration when developing the first version of the prototypes. These interactions match the example scenarios created in the mind map found in figure 14. When looking at the abilities, a lot of the abilities mentioned matched those that were already taken into consideration when implementing the first version of the toolkit. However, some of the participants also mentioned that they found it important that should be able to manage activities and keep time. This indicates the relevance of a component that can track time in the toolkit. Additionally, some of the participants mentioned that they believed it is important for the prototype to be able to learn. However, such an advanced prototype would require the access to the internet or a large database and would require the development of some sort of neural network component. This would be beyond the scope of this project as such features would require a significant amount of additional time and research to be spent on such an technological infrastructure. Note that some of the components in the toolkit already have a built-in infrastructure for facial recognition and tracking, and voice recognition and is why these do not need an additional machine learning platform. When looking at the construction mechanisms materials, it can be concluded that the majority of participants imagined plastic being the basic material used to construct. However, it also showed that it is important to inform the users beforehand about possible extreme conditions in which the toolkit prototypes would fail, such as extreme heat or rain. This means that no changes will be made to the construction mechanism of the initial version of the social robot toolkit, but also means that the qualitative test regarding the expectations of potential end users failed. It is suspected that this is a result of using a survey to gather qualitative data, rather than interviewing in person. How this can be tackled in the future will be discussed in **chapter 6:** *Recommendations & Future Research*. When looking at the most relevant aspects of co-design, the most important features mentioned by the participants were adjustability, ease of use and ensuring that also the co-design participants are having fun. These were all taken into consideration when developing the initial version of the social robot toolkit. The nuts, bolts and connection component mechanisms are easy to understand and allow the HRI-developer to easily adjust their created prototype. The use of this simple construction mechanism combined with the simplicity of the majority of components within the toolkit, would allow the co-design participants to more actively engage in the co-designing process. Thus, with regards to the requirements for co-design no changes will be made to the social robot toolkit. Finally, a majority of the survey participants indicated that the first version of the toolkit was in line with their expectations of the toolkit. One participant mentioned that they would also like to see the social robot toolkit having wheels for the robot, however when looking at their reason as to why they would want wheels, it can be concluded that this participant was thinking of a more industrial robot rather than a social robot. Another participants mentioned that it was not in line with that they expected, because the first version of the toolkit also included components for movement, however, the rest of the toolkit generally in line with that which they had in mind. From this can be concluded that no major changes will need to be made with regards to the first version of the social robot toolkit for now.

3.6 Reiteration prototype

The conclusion in 3.5.3 not a lot of changes need to be made to the toolkit with regards to the connecting components, material, and construction mechanism. With regards to that which needs to be changed, the conclusion of the user concept feedback indicated an importance for prototypes to be able to manage time and is why the Grove RTC module was added as a feature component to the toolkit. This component uses a lithium cell battery to provide the time to the main controller board and can be seen in figure 33.

Figure 33: Grove RTC module used for timekeeping.

With this component, the social robot toolkit would provide the HRI-developers with a way to easily track time in their prototypes, as it is a component that is built for use with the Grove Shield and Arduino. This was the only major change made to the toolkit as a result of the stakeholder interviews. No changes were made concerning the other components in the toolkit.

4 Evaluation research

Now that the prototype of the toolkit has been iterated upon and received adjustments with regards to its design, it can now go through the second phase of the user research. This part of the research will focus on evaluating the practical usage of the toolkit. The evaluation research has been divided into two parts. These are the user evaluation, where the toolkit will be put to use by other users from the target group, and the self-evaluation, where the toolkit will be used by the researcher themselves. The self-evaluation was added to the evaluation research in order to get additional design feedback relating to physically interacting with the toolkit. During these user evaluations, the users will be asked to build a social robot prototype using the toolkit. In order to prevent the users from becoming too tired during the evaluations, the usability session will be around 45 to 60 minutes. Note that this timeframe does not include the time needed to explain the toolkit, how the components and software work. It is also important to note that this part of the research also complies with the Covid-19 regulations in 2020 [49]. How the research complies with the regulations of the government can be found in the method of each research. Note that the research procedure has also been approved by the ethics committee of the EEMCS faculty of the University of Twente (RP 2020-74). After having used the toolkit to build a prototype within the given timeframe, there will be a reflection session where the users will give their formative feedback on the usage of the toolkit. These will be noted by the researcher and the notes will be presented in the results. Then these results will be analyzed, and a conclusion will be drawn. This results will be analyzed and how it relates to the main research question, which is “*How to design a toolkit that facilitates the rapid prototyping of social robots in a co-design scenario and is usable by entry-level users*?”. From the conclusion, there will be looked at how there can be built upon this research and this will be mentioned in the recommendations chapter.

4.1 User evaluation

This section will focus on evaluating the practical usage of the toolkit by others. The goal of this research is to gather knowledge about the user's usage experience and learning how effective the toolkit will be in prototyping social robots. The method will elaborate on the research procedure that will be used to gather this information from the users. Afterward, the results from this feedback session will be noted and analyzed together with the results from the Self-evaluation. Together these will lead to a conclusion of the usage evaluation.

4.1.1 Method & Procedure

The goal of this project was to develop a toolkit that would enable people from different backgrounds to develop social robot prototypes through co-design. From example use case scenarios and mind mapping, the usage process of the social robot prototyping toolkit was mapped out into a general process diagram. The most important roles that directly relate to the toolkit usage have been indicated using the squares seen in figure 34.

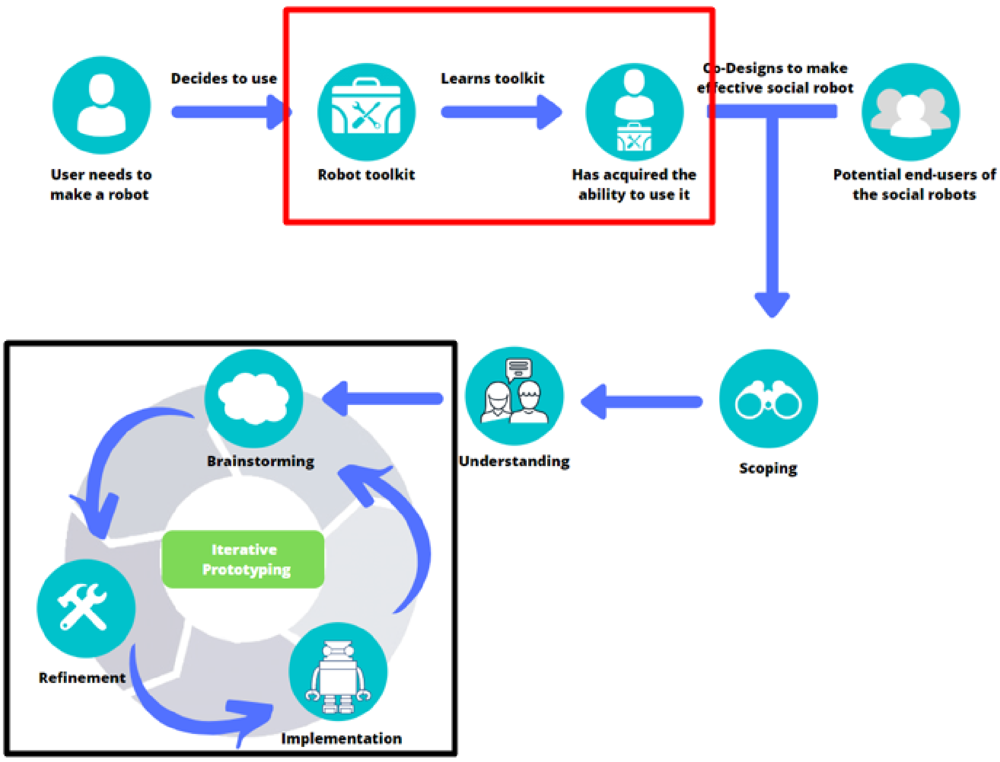

Figure 34: Toolkit usage process showing the general toolkit usage. The red square indicates the start of using the toolkit. The black square shows the toolkits by HRI-developers during the co-design sessions.

Since these are the two most important parts of the usage of the toolkit, the user toolkit usage research will be divided into two parts. The first part of the user research will focus on the learning process of using the toolkit (red square, figure 34). This part thus has an emphasis on the requirements that relate to ease of use (requirement 1a,b,c). The second part of the research (black square, figure 34) will focus on the users ability to construct a simple robot prototype and adjust their design (requirement 2,3).

Study setup

In the ideal scenario, users would have to sit at a table and so interact with the toolkit to construct the prototype. However, this is not possible at the current time, as the user research has to comply with the previously mentioned COVID-19 regulations in the region. In short, physical contact between users is not allowed. A solution to this is to enable the research participants to interact with the social robot toolkit through a video call. The participants would instruct the researcher (who has the toolkit in front of them) through a video call that they would like to do with the toolkit. The researcher would then function as their tool for physically interacting with the social robot toolkit. Additionally, they would be able to control the PC of the researcher through either screen sharing or a third party computer controlling software like TeamViewer for programming and/or software changes.

When doing this form of qualitative research it is important to ensure that it is of good quality. This will be done by taking into consideration that the research has to comply with the four standards of quality [52], which are credibility, transferability, dependability, confirmability. These standards were kept in mind when developing the study setup.

Step by step procedure

Since the toolkit will ultimately be used in co-design. Each of the social robot toolkit evaluation session will consist of three people. One being the researcher, and two being the participants. By using multiple participants, it ensures for a more realistic use case scenario for the participants, due to additional teamwork elements that are included. These can range from problem solving together to discussions together. Additionally it promotes time efficiency by providing the researcher with the qualitative feedback of multiple participants within the same period in time. The participants will be placed in groups of two, and will be given a date for when they will be video called. Note that each participant will be grouped with another participant that they already know personally to a certain extent. This is done in order to reduce awkwardness between the participants and encourage engagement with each other, the researcher and the project. On the agreed date the video participants will be video called through Skype and the user evaluation will begin.

Part 1: Testing ease of use

The evaluation first will start off with the formal introduction session. During this session the researcher will provide information with regards to the research and the roles of the participants within the research. This will be done either through either video call or by letting the participants read the research information brochure found in appendix 1. It is estimated that this will be around 5-10 minutes long.

The following 20 minutes will focus on allowing the participants to learn about the toolkit. In order to be consistent, each of the interviewed groups will be asked to carry out the same tasks. These tasks will be carried out the by groups in order for the researcher to observe how easily the participants can get familiar with the components. In order to ensure the ease of use of a different set of components, the participants will be asked to upload an example program to 2 grove components, an Arduino connected component and a shield component. These tasks are described in more detail below.

The participants will be asked to:

- Connect and program the Grove Speech recognizer

During this task the participants will be tested on how easily they can follow instructions on the grove website in order to get the speech recognizer working. They will start with accessing the website, understanding its contents and following the given steps. Then these steps would range from instructing the researcher on connecting Arduino to the Grove Shield, to connecting the Grove Speech recognizer to the Shield and uploading the code. And testing the Speech recognizer.

- Connect and program the Grove 8x8 LED matrix to their own eye animation

After completing the previous task, the participant then has experience in navigating the Grove website along with its instructions. Now they will be tasked to follow the instructions of the grove website, which require the use of an additional website for easily programming or animating the eyes of the LED matrix. This phase again tests their ability to connect the a Grove component to the Grove Shield, Arduino and computer.

- Connect and program the servo motors for simple rotational movement

During this task, the user will be tested on their ability to find information with regards to a non-grove component that is interfaceable with Arduino. They will be tasked to go onto the internet, find information themselves, and upload it to the servo in order to get it moving.

- Connect and program the program the OpenMV H7 shield to track the users face

For this task, the user will be tested on their ability to interface one of the components directly with the computer. Additionally it will allow the user to experience the use of an additional IDE using a different language (python) than the one Arduino uses (C++). They will be tasked with exploring the IDE’s examples and uploading them.

During all of these tasks the researcher will observe the participants while completing these tasks, and take notes. Additionally, the researcher might provide hints to the participants in case they are experiencing difficulties in completing the task. It is important to note that for this part of the evaluation, the PC of the participant will be used. This means that the participants ability to install Arduino libraries or IDE's will not be tested. However, it is not a problem as the main focus of this part of the research is to analyze the participants learning the usage of some of the components, rather than installing software and libraries. When the participants have completed all of the tasks within the given 20 minutes, they will start with the second part of the user evaluation. In case the participants have not completed all of the tasks in part 1 of the user evaluation, the researcher will politely ask them to stop in order to start with the second part of the user evaluation.

Part 2: Testing construction and prototyping

The researcher will inform the participants that part 2 of the user evaluation will start. The participants will be given access to the rest of the toolkit and will be asked to create a simple offline social robot prototype. In order to save time, participants will be tasked with constructing a social robot using the components from the previous part of the evaluation. The specific type of social robot they will be tasked with creating will be a social receptionist prototype. This is a simple social robot that can look around, stare, and detect faces and hear vocal input. The receptionist design robot was chosen so that they could use the components from the previous part of the report. This would allow the participants to focus more on constructing a simple social robot prototype, rather than having to learn and tinker with additional newer components. Throughout the task completion process, the participants will need to combine several of the feature components, along with constructing a basic design for the prototype. At one point in the evaluation, the researcher will ask the participants to make a certain adjustments to their prototype. This is done in order to observe how efficiently the participants can adjust the prototype. With efficiently is meant the ease and speed of readjusting the prototype. During this process, the research will observe the participants while they try to complete the task. Note that this part of the research is will last 25 minutes. After the 25 minutes of part 2, the researcher will *triangulate*[2] their notes on the experience by not only observing the participants but also interviewing them. During this interview, the researcher will ask the participants will go through the requirements list and ask the participants whether the toolkit meets the requirements according to them. Afterward, the researcher will reflect on their observation by *member checking* the participants. During this implementation of member checking the researcher will elaborate on that which the participant, for example, struggled with or check if the observations and notes made by the researcher are in line with that of the participant.

All of the user evaluation sessions will be recorded after having given permission and signed the consent form. After the evaluation session is complete, the researcher will match

[2] Member checking & triangulation descriptions [53].

their notes and observations with the saved recordings. The researcher will publish their findings in the results and analyze them in order to reach a conclusion for developing the prototype.

4.1.2 Results

This section will discuss the results found in each of the group evaluations. With results is meant the qualitative feedback from the participants in the form of notes that the researcher took during their interaction with the toolkit. Each of the group results will be divided into an introductory part, followed by the observations of part 1, then the observations of part 2, and then a general feedback and reflection section.

4.1.2.1 Group 1

Note that for this group, initially there were two participants planned. However, on the date of the evaluation one of the participants called it off due to personal reasons. The researcher stepped in as the person the current evaluation participant (from now on referred to as P1A) could discuss the components of the toolkit with. It is also important to note that P1A has a background in “Advanced Technology” at the University of Twente. This means that they do have experience in programming and working with electronics.

After instructing the participant on their tasks, they started with the execution part 1. They seemed intrigued by the components and started looking at them one by one as they were presented by the researcher through a videocall. At one point P1A mentioned that they would like the components to have clear labels on them in order to quickly see the name, rather than having to look it up. For the grove components they were directed to follow the steps of the Grove website. Initially they were confused when trying out the grove components, as the instructions mentioned the use of a Seeeduino V4.2 [54], rather than an Arduino which they were using. The researcher had to mention that the use of the Arduino IDE for programming the controller board was also possible. After following the instructions, they encountered troubles with uploading the code to the Arduino. The problem was a more common Arduino problem relating to an incorrect COM port and board setting within the IDE and was thus quickly resolved after discussion with the researcher. Within around 10 minutes they were able to get the Grove LED 8x8 matrix working. Note that in this evaluation the participant did not use the online tool for animating the eyes. They used example code provided by the libraries. The researcher allowed this in order to save time. The next component that was tested was the speech recognizer, similar to the previous Grove component, they followed the steps given on the website. However, again encountered a problem relating to the Arduino. After trouble shooting for a few minutes, the participant managed to get the speech recognition working. This took around 10 minutes.

This indicates that the time needed to complete part 1 of the research required more than the previously estimated 20 minutes. The researcher asked if they could extend the total duration of the evaluation research in order for P1A to complete their tasks and P1A complied. The next component needed for the evaluation was the large servo motor (HK). They did mention that it is important to differentiate Grove components and non-Grove components in the toolkit, in order to better know what instructions to search for. P1A then mentioned that they did not know what to search on the internet in order to get the instruction manual of the toolkit. After a small discussion with the researcher they ultimately google searched “Servo Arduino setup”. They navigated different instruction websites and ultimately chose one that explained the setup stepwise with pictures. P1A chose this one as the use of pictures simplified the prototyping process. They got the servo motor rotating and were startled at how simple it was. This part took around 7 minutes. The final component that was tested was the OpenMV camera module. Since they were required to do the similar steps as the previous tasks, they easily knew what to search on google and how to find a good website that showed them how the module works. P1A initially had trouble finding a website that was straight to the point instead of providing a lot of unneeded information. They followed the steps on the final website they chose and ultimately were able to get the component working. Since they mainly used examples, in the previous tasks, they also knew that they could easily find examples for the camera module in order to get it working in a simple way. Do note that P1A showed and mentioned a distaste for having to use a different IDE (OpenMV IDE) for this component. Additionally, they found it confusing to go from one programming language to another. However, they did liked that the IDEs came with large number of examples that they could try out.

After completing task 1, they were asked to build a receptionist-like social robot. Initially P1A showed a shocked expression, and mentioned that they did not know if it would be possible to construct a complete receptionist-like social robot within the given time frame. The researcher acknowledged this and asked if they could think-aloud and at least mention how they would build it. P1A then proceeded to analyze the construction mechanism that was present in the toolkit (connecting components). They mentioned that they found it a straight forward mechanism and started attaching these connecting components to each other. After connecting some of the components together, they mentioned seeing that it sometimes requires too much force to twist the bolt through the hole of the connection mechanism. This was caused by the 3mm bolt. The researcher then mentioned that there is also a 2.5mm bolt option, they then agreed that they would use that and found it easy again. No complex construction was created as the researcher observed a decline in P1A’s enthusiasm.

In the end the researcher and P1A together reflected on their evaluation of the research. The participant acknowledges that getting familiar with the components in part 1 were easy and efficient, however they did mention that there needs to be a place where they can find common IDE related problems, in order to simplify the troubleshooting process. When asked to rank the difficulty of the components they mentioned that they were all very easy. Additionally showed that they liked the construction mechanism and hardware present within the toolkit, and said that they do see themselves constructing prototypes using it if they were given enough time. P1A mentioned that for rapid prototyping they would prefer one single frame that could be used for a majority of the expected prototypes. Then it would be much faster to connect the needed components to this single main frame construction. However, after discussing this with the researcher, they acknowledged that this frame could also be built using the components within the toolkit, and could then be reused for different prototypes. When briefly looking at the software they mentioned that if they took the time to read it out and try and understand the software that it would be possible for them to understand the program and be able to reuse or adjust it.

4.1.2.2 Group 2

This group consisted of a participant with a background in health & care (from now on referred to as P2A), and a participant that had a background in building construction (from now on referred to as P2B). After giving a brief explanation of the toolkit, its components and the research, the participants started with the first in part 1.

Similar to the previous participants they were shown and asked to carry out the given tasks. Note that P2A and P2B both mentioned that they did not know anything about Arduino. . P2A described having to use the Arduino IDE as a brick wall, because they were unfamiliar with it. This resulted in the researcher needing some time to explain the basic layout of Arduino. Additionally the researcher explained what microcontrollers are and what some of the other components needed for part 1 actually are. After having explained to the participants (+15 minutes), they were able to instruct the researcher properly. After going through the steps for getting the Grove LED matrix to work, they mentioned that it was a lot easier than they expected (~7 minutes). When asked what “it” was, they mentioned following the steps and connecting the hardware components. However, because the researcher already installed Arduino and the libraries, P2A also mentioned that if they were required to install Arduino first, along with the libraries required for the component they would need additional time. This is because it is something neither P2A or P2B has ever done in their career or education. Note that during this process they both mentioned that if a problem were to occur relating to for example, the wrong COM port in Arduino, that they would require a lot more additional time to troubleshoot as they are not familiar with the software and its most common problems. Also note that these participants did rely more on the researcher to provide them with direct answers to problems they encountered, resulting in less time spent per task. The next task was the speech recognizer. Similar steps to the previous one were taken in order to complete this task (~5 minutes). In the end P2B described this task as being “pretty doable”, however, same problems were encountered as they had no experience with coding and the Arduino IDE. For example, they did not know how to use the Serial Monitor in the Arduino IDE to test whether the Grove component was working correctly. Due to this the researcher quickly explained it to them. After completing the second task, they started with the third task, which was getting the servo to work. Similar to group 1, due to the component not having a clear name on it, they did not know what to search in order to get it to work. In order to save time the researcher just mentioned this to them. Then they quickly searched “Servo Arduino Setup”, website and were able to complete the task (~6 minutes). Again these participants faced problems relating to the Arduino microcontroller. For example knowing what the pins are and what the example code they pasted was actually doing. However they did find it extremely helpful that the instructions included pictures. Then they started with the final component of the final task in part 1, namely the Open MV cam component. They did not find this step particularly hard, as they described the steps that they had to take being very similar to the previous steps, which is finding out what component you’re working on and navigating the internet for a step by step procedure for setting it up. Which is how they ultimately got the final component working (~6 minutes). However, P2A did mention that it can sometimes be hard to find a document that is “straight to the point”. Additionally they mentioned that most f the instructions they found were “too long and too much”.

After completing the tasks in part 1, they were instructed to create a receptionist-like prototype using the components within the toolkit. P2B was first interested in knowing what other components were in the toolkit. Since it is important to know what other capabilities the social robot toolkit has, the researcher showed and briefly explained what other possibilities the toolkit had. They then asked to be shown the connecting components needed for construction and liked it. It seemed like they did not want to spend the remainder of their time watching the researcher construct a prototype, and the researcher concluded part 2 of the user evaluation.

When reflecting together on the user evaluation with the participants, they mentioned that the most difficult part is having to program and use new software such as Arduino IDE and OpenMV IDE. Additionally, they mentioned that they feel that part of their ability to use the prototype is caused by the lack of basic Arduino knowledge. However, P2A also said that after getting a few of the components to work, they were able to get the other components to work, as they were indirectly taught a way of tinkering with the hardware. They both acknowledged that even after around 30 minutes they made a lot of progress with regards to learning about prototyping with electronics. Additionally, P2A mentioned that they liked the idea of including a construction mechanism for developing a prototype in their toolkit, as they themselves would have no idea on how to physically construct a prototype if they wished to do so. Additionally P2B mentioned that they liked the fact that the toolkit itself comes with a variety of different components that they could use, because it allows for a more customization when prototyping. Both the ultimately participants agreed that if not for the "lack of programming wall" they would be able to rapidly prototype using the toolkit.

4.1.2.3 Group 3

Group 3 is an exception of the other groups, as these participants were able to physically interact with the toolkit. This was possible due to them being able housemates of the researcher that constructed the toolkit. Note that this research still complies with the covid-19 regulations. One of the participants had a background in building construction and care (from now on referred to as P3A), whereas the other participant is studying Computer Science at the University of Twente (from now on referred to as P3B). After being introduced to the toolkit, its components and the goal of the research, they were asked to complete part 1 of the research.

They both started off looking at the different components and were tasked to first start prototyping with the Grove LED Matrix. Initially both P3A and P3B struggled with what they had to search. However, after the researcher instructed it P3B found the website. P3A then read the steps, while P3B executed the instructions provided by the website. P3B mentioned that he did not have a lot of experience with working with hardware, but did find very easy to follow the instruction steps for the Grove LED matrix. It was observed that this task was completed with relative ease, however, it was observed that a P3A and P3B also spent a lot of time talking to each other. This caused the task completion time to be in total around 12 minutes. Now they were both tasked with prototyping the Grove Speech recognizer. P3B was able to quickly get the components working. This lead to P3A giving less input on the design, and resulted in them playing around with the construction components. However, similar to the other groups the component did not immediately work as intended and they were requested to troubleshoot Arduino and the connections they made. P3B mentioned that they have a lot of experience debugging the software, however, do not have a lot of experience troubleshooting hardware. Since it is a very common Arduino problem, (again relating to the USB port used), the researcher quickly informed them on how to fix it and the complete the task (~6 minutes). Then they were tasked with getting the large servo to work (HK) to work. After looking online for instructions on how to connect the servo to Arduino a step by step process was found. P3A showed interest in participation with the hardware again and instructed P3B in what pins go where on the Arduino. Note that it was observed that P3B had the tendency to always briefly read the code first, in order to get a better understanding before pasting it to Arduino IDE. Then it was observed that P3B had the tendency to also explain what was happening in the example codes to P3A. Again, they mentioned that completing the tasks is not difficult, however a lot more time is spent on discussing and explaining the toolkits components to each other. After getting the servo to rotate using example code, P3B adjusted the code to show P3A what would happen (total 12 minutes). It was observed that they passed the 20 minute mark and were asked if they wished to start with part 2 of the user evaluation. However, both participants mentioned that they would like to complete task 1 first as there was only one component left. Since it the procedure that had to be taken was similar to the previous sections, the participants were able to get the OpenMV camera working. P3B noticed that OpenMV IDE used python rather than C/C++ and showed interest in how the components would work together.

Now part 2 of the user evaluation started. P3B showed signs of enthusiasm in getting a grove component to cause the output in the servo. They first wanted to control a servo using the Grove Speech recognizer. However, both did not know how to interface the servo with the Grove Shield. P3A then proceeded to search through the rest of the components within the toolkit, and they found the Arduino MEGA. Then P3B proceeded to connect the Grove shield to the Arduino, while using the other non-used pins of the Arduino MEGA to control the output of the servo. It was observed that P3A could not actively participate in programming, however, they still spent their time playing around with the construction components. After some time P3B mentioned that they like the concept, but that it would require more time to interface multiple components with each other through Arduino and that they were not interested in doing that at the time. The researcher then concluded part 2 of the user evaluation.

During the reflection session the researcher asked what they liked and disliked about the toolkit. P3B mentioned that they like the idea, however felt like there was a big difference in skill needed to connect the components through software. P3A supported this statement, as they felt that without P3B’s assistance in programming they would might have slightly more difficulties in execution of the tasks in part 1. With regards to the construction mechanism they said that they could see themselves using it to construct a prototype and saw the potential in being able to quickly adjust the components by loosening the bolts. P3A added that they particularly enjoyed the connecting components being within the toolkit, because it gave them something to do while P3B handled the software of the toolkit. However P3A also mentioned that they had difficulties getting the bolts through certain holes in the construction. They noted that is possible, but that the hole was extremely tight, causing them to use excess force to screw the bolt within the toolkit. Both participants stated that the toolkit was a good way to learn more about the hardware and software of electronics and mentioned that it might also be applicable in education.

4.2 Self evaluation

This section will cover the self-evaluation part of the social robot toolkit. The method and procedure explain what steps will be followed in a way that makes it valid qualitative research. Then the results will discuss what came out of the self-evaluation session.

4.2.1 Method & Procedure

An autoethnographic approach will be taken in order to provide additional feedback on physically using and interacting with the prototype [55]. As mentioned earlier, this part of the evaluation was added in order to receive additional information with regard to physically interacting with the toolkit. This methodology relies on the personal experiences of myself as the researcher when prototyping with the toolkit. It is important to note that during this evaluation there might be a possible bias when evaluating this. In order to combat this, I will do my best to be as transparent and honest as possible when reflecting and providing feedback on prototype usage. Additionally, I will try to focus on both the good parts and the bad parts of the research and be as critical as possible when approaching these [56]. This will ultimately lead to an approach that is as objective and systematic as possible. This evaluation will be divided into two parts. The first part focuses on the experiences with regards to the first time prototyping with the toolkit, and the second time will focus on rapid prototyping with the toolkit.

Part 1: First prototype

During this part the I will reflect on my experiences and memories of the first time creating a prototype. The design of the prototype was based on a kismet-like robot. This means that I was tasked with creating a robot that had vision, could hear, and move its head in different directions. The time I spent on this was around 2 days. However, the number of active hours ranged from 3 to 4 each day.

Part 2: Prototyping with speed

For this part of the evaluation, I will give try to place myself in the shoes of an HRI-developer that does not yet know what type of social robot I need to make. At the start of the session, I will give myself 1 hour to construct a prototype of a random social robot. I will write down 5 different types of the social robot and I will select one randomly. Then I will have to construct this social robot within the given time frame. After the session, I will reflect on my experience as the HRI-developer.

4.2.2 Results

This section will discuss the results of part 1 and part 2 of the self-evaluation. Note that not the entire process of prototyping will be described here, only the major points retrieved from my notes and memory.

Part 1: First prototype

The first prototype that was developed can be seen in figure 35.

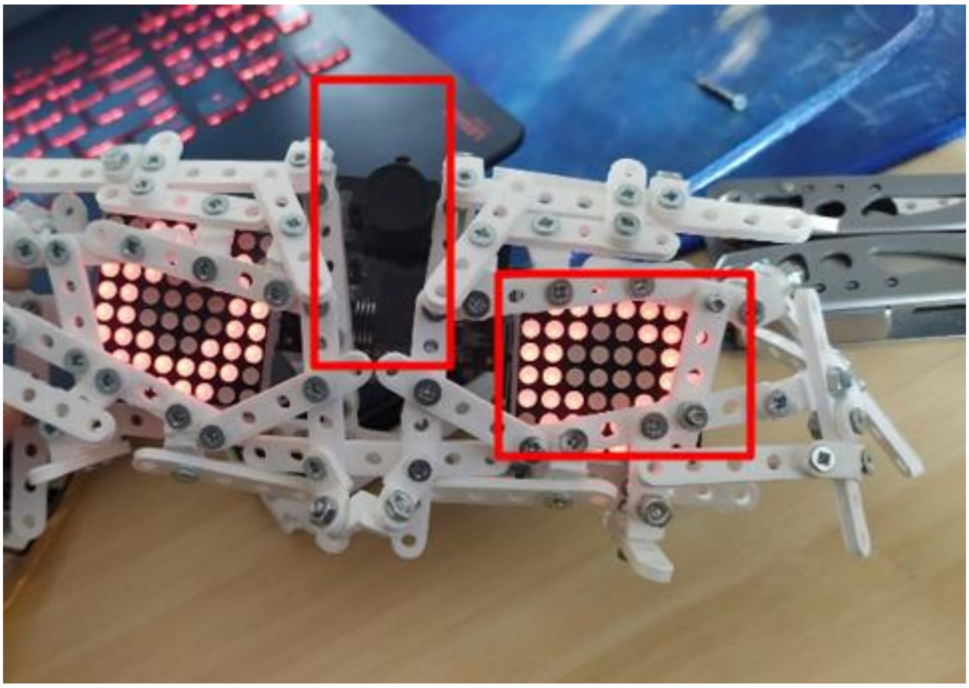

Figure 35: First prototype made within 8 hours (testing components and programming included). The left red square shows a camera module for object recognition. The right square shows the robot's left eye, which was also animated to look around.

As seen in figure 35, the first prototype I started with the head of the social robot. Since the eyes were most important I also created a simple eye animation provided by the Grove website. When constructing the social robot, I noticed that the 3mm bolt could fit easily through some holes of the connector components, and difficult through others. I assumed that this was caused by the speed at which they were 3D printed. At first, I found it a nuisance to have to use additional power to get the bolt in the connector component. After a while, I realized that it has its pros and its cons. The easier the bolt fit into the hole, the looser the bolt could become, whereas the tighter the hole, the longer it would take you to connect two components. However, after completing this you would have a very stable construction. Note that for the prototype in figure 35, I tried testing out how complex of construction was possible with the components of the toolkit. When looking at the eyes and their connector components, I concluded that it is possible to create more complex constructions, however, the downside was that it would require additional time. And the more complex the construction, the more tedious the connecting of components. This is because at one point you will have to nuts screws through other components that are in the way of easily connecting them to the bolt. I also noticed that some of the PLA connector components were slightly bent. I assumed that this was again caused by the way they were 3D printed and extracted from the 3D printer. However, this did not become a problem when having to connect the components. After having built the eyes and forehead of the robot I started building the Arduino (which would be the input-output processing unit) and finding ways to connect them to the backside of what I created. When I realized the time it would take to program the connection between the LED matrix modules and the camera I got discouraged and decided to work on the mouth and neck of the robot. For this task, I used the larger servos of the toolkit (HK). These would be placed on a heavy base. I decided to use the power bank to connect the neck servo to a base. Even though the connection between the Servo and base was stable, it still moved a little around. This is why I also placed duct tape to make it more stable as seen in figure 36.

Figure 36: Servo and power bank base of a social robot.

When developing the neck mechanism of the robot I found that it is possible to connect multiple servos to each other to create more complex 3D movements. However, I noticed that if the construction that had to move around became too heavy, the connection between the servos and the rest of the construction would require additional support. This was done by screwing the connector component to the servo. Another problem encountered was when screwing the nuts and bolts too tight for a connection. When doing so the smaller 90-degree components will break as seen in figure 37.

Figure 37: Connector component breaking as a result of the prioritizing tightness in the nuts and bolts. This is indicated by the red arrow.

At one point I noticed that one of the eyes of the robot prototype was incorrectly placed (90-degree offset). However, I only had to unscrew two bolts, rotate the eye, then re-screw these bolts. This was when I saw the true value of being able to rapidly adjust the prototype and was happy that the construction mechanism facilitated this.

Part 2: Prototyping with speed

For testing prototyping with speed, I randomly selected one of five options for social robots that I would have to create. The prototype that I had to create was a social pet robot. From the literature review, I knew that one of the major components that would be required for making this prototype would be touch. Which is why I prioritized connecting the touch Grove touch sensors to the Arduino. After only an hour of constructing and programming, I managed to develop the construction seen in figure 39 and figure 40.

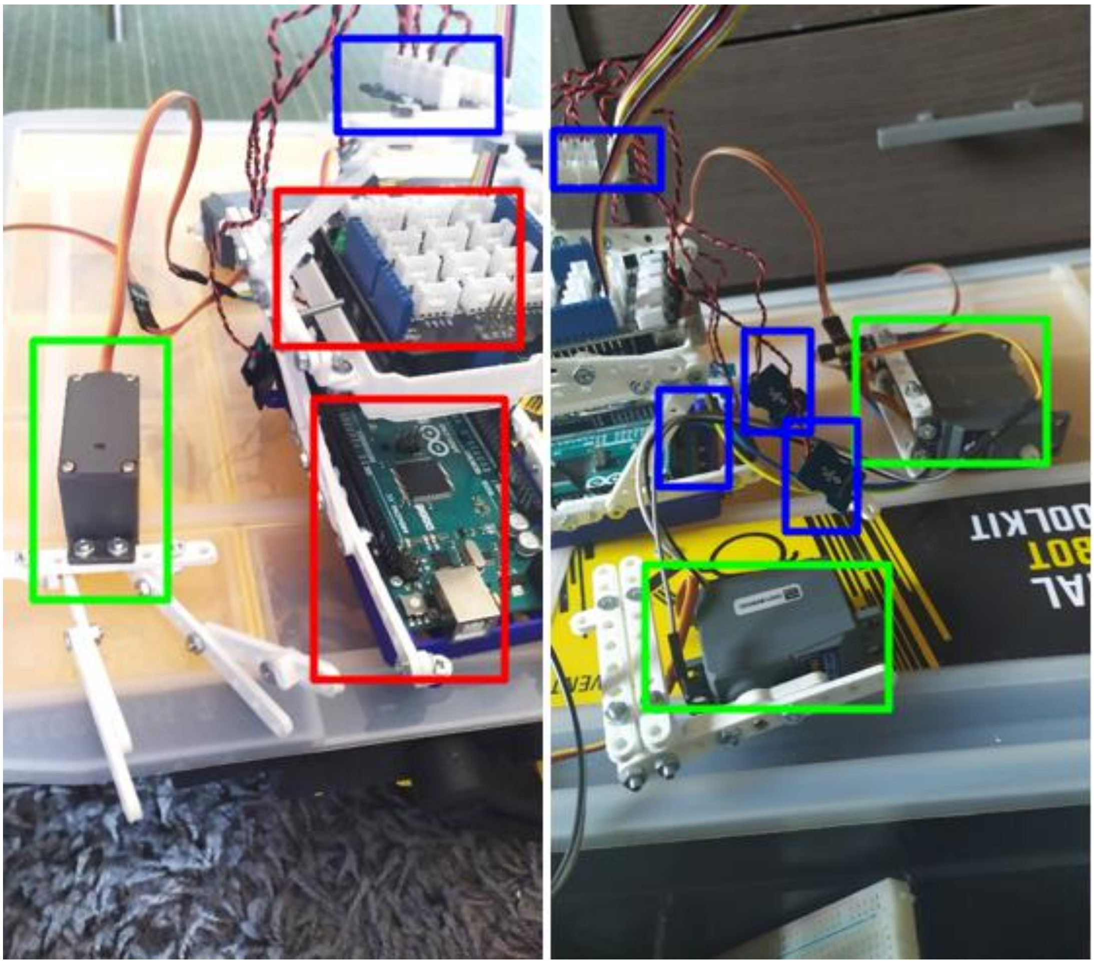

Figure 39: Two images of the dog-like designed prototype progress in an hour. The red squares are the Arduino UNO (+Grove Shield). The green squares are some of the servos and the blue squares are the Grove touch sensors module + touch sensors.

The full construction can be seen from two angles in figure 40.

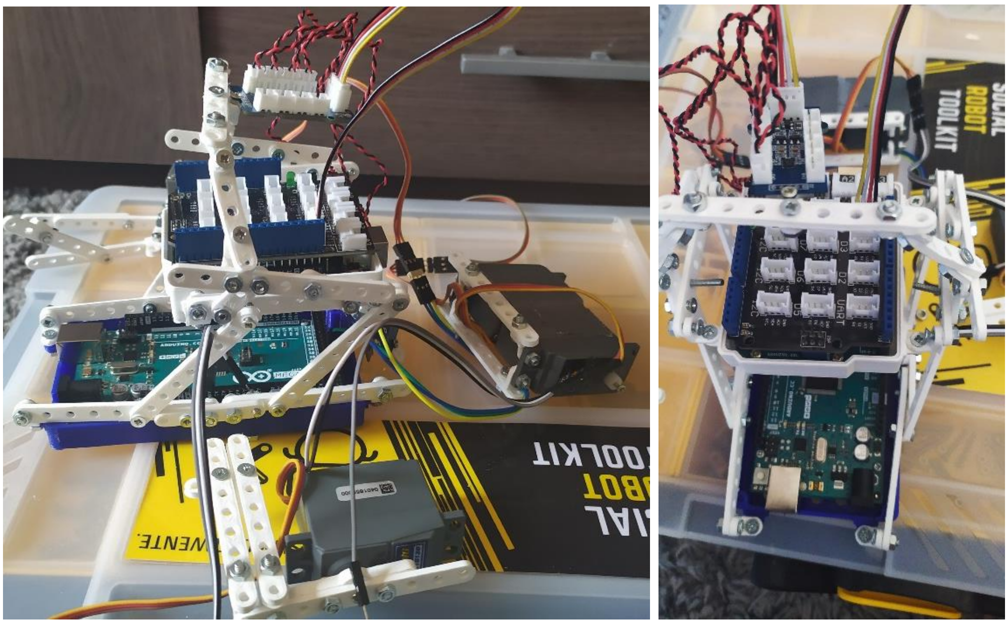

Figure 40: Image on the left showing the construction as a whole from the side. The image the view from the top.

During this session, I prioritized the construction of the prototype, rather than stability, which is why the construction itself was not as that stable. This meant that the more stable I wanted the construction to be, the more time I would have to put in tightening the nuts and bolts. However, within the given timeframe I was able to develop a basic layout for the main body of the social dog-like robot. The main body is seen in figure 40. would contain the main controllers of the prototype. When trying to interface the feedback from the touch sensors and the servos, I noticed that I spent a lot of time also troubleshooting and trying out different rotational behaviors for the servo motors. At the end of the 1-hour session, I did not manage to fully create a behavior between the touch sensors and the servos as the time was too little.

5 Conclusion

The goal of this research project was to develop a toolkit that can be implemented in co-design to develop social robots and still be usable by entry-level users. To start the process of designing and developing such a toolkit, first, there was a literature review to get a better understanding of the field of social robots and co-design. From the inspiration received from this phase, the ideation phase started. In this phase, possible use case scenarios were mapped out. From this, it was possible to get an overview of how the toolkit would be used in practice. From this overview came a list of requirements. In the realization and implementation phase, these were to be tackled. After combining the solutions for these requirements, they were placed into one single toolkit. This was the first version of the social robot toolkit. Afterward, the toolkit received some brief feedback from some of the stakeholders. This feedback session lead to a small iteration of the first version of the social robot toolkit. The then adjusted version was used in the user evaluation. This was done to determine if the toolkit could be used in co-design for the development of social robots. Qualitative feedback was gathered from potential end-users from which some directly interacted with the toolkit and others indirectly interacted with the toolkit.

The feedback on the toolkit differed depending on the educational background of the person evaluating it. All of the participants that interacted with the toolkit mentioned that they do believe that it can be used to develop simple social robots. The user evaluations also indicated that the participants enjoyed the first part of the evaluation where they had to complete tasks by getting some of the hardware components to work. This is said because when asked to stop and go to the next part of the user research, all of the participants declined. The completion time of user evaluation task 1 differed per group. A large determinant of this variation is the background of the participant, as well as how much time was spent discussing or explaining certain components amongst participants themselves. However a rough average estimate can be given for the completion time, which is around 30-45 minutes.

The participants who had some experience in programming were able to more easily and quickly understand what had to be done with regards to programming the components and troubleshooting. Those who did not have any experience in software or Arduino however did have trouble navigating the Arduino IDE, programming, and troubleshooting the hardware. An estimate of the time spent troubleshooting the software IDE is around 5 minutes. Initially, it was assumed that through the use of coding examples, participants would be able to understand what was happening in the software and relate it to the actions of the hardware. Then they would be able to adjust and create their own modified components. However, this was wrong assumption and was only applicable to those that had some experience in programming. From the user evaluations it seemed that in order to combine the components of the toolkit, still a basic understanding of programming and Arduino is required. Additionally, most of the participants mentioned the confusion between having to use different software IDEs depending on what component they were working with and had to program. These findings suggest that one coherent programming IDE is also required in combination with the hardware of the social robot toolkit. Such a programming IDE would have to be interfaceable with the different components of the hardware and would have to be intuitive so that those who do not have a lot of experience with programming are still able to make adjustments to the code.

The group evaluation results also indicated that it is a good feature to include the (non-technical) construction components that will be used for prototyping in the social robot toolkit itself. This is because according to the feedback and observations, it can give those who are not interacting with the hardware or software components of the toolkit something to do. By doing so, it allows them to still feel engaged in the co-design prototyping session and contribute to the prototyping process.

Another recurring observation was the toolkit accidentally also being used as a way to educate those who do not have a background relating to electronics to learn about basic hardware and software. When the toolkit is used in a group where no one had a background in electronics and software, they all agreed that it was a simple way that they could use to learn (given the time) to get a better understanding of the field. When the toolkit was used in a group where one person had a background in electronics and the other did not, it was observed that they were intrigued by the components and asked the other participant to explain it to them. This ultimately indicates that the way this toolkit is built can also be used as a learning experience for those using it.

When looking at the construction mechanism used for building prototypes, all of the participants agreed that they could use it to rapidly build a prototype. However, the results from the personal evaluation indicate that this is only true to a certain extent. When rapidly prototyping (constructing) it comes at the cost of the stability of the prototype and when stability is prioritized, it comes at the cost of the construction speed.

Ultimately, this social robot toolkit does meet most of the requirements mentioned in table 3. It is easy to start with, provides the capability of using a different set of hardware features, and does facilitate the rapid prototyping of simple social in co-design. However, the results suggest that it still does not fully meet the requirements relating to the software (1b, 2c), which were beginning to program the components and processing the data for the artificial behavior or interaction between components. This results in the toolkit being used for prototyping, however only to those that have a basic understanding of programming as it is not as user-friendly towards those who are not familiar with programming. Nonetheless, additional research will be required to determine whether meeting of these requirements fully answers the question; *How to design a toolkit that facilitates the rapid prototyping of social robots in a co-design scenario and is usable by entry-level users?*

In short, the key findings are:

- Clear, straight to the point instructions are important (also including pictures).
- Simple social robots are constructible using the toolkit according to the users (however a large emphasis is put on simple social robot, this toolkit does not e.g. contain components e.g. advanced machine learning or access to the internet).
- Users seemed to enjoy the learning phase.
- The current version of the social robot toolkit is mainly accessible only to those with a more technical background (working with hardware and programming).
- Unified & simplified programming IDE is also needed.
    - Users experience difficulties in having to use different IDE's
    - Simplified programming IDE needed for low-entry user accessibility (e.g. graphical programming interface)
    - Built-in examples are extremely important for understanding components.
- Important to also include components co-design participants can interact with, because it keeps them engaged in the prototyping process (e.g. construction components)
- When developing a toolkit that is accessible to both experienced and entry-level users and will be used in co-design, you automatically also create a tool for education on robotics and electronics.
- Further research required where physical interaction with the social robot toolkit is implemented in the user evaluation, plus longer sessions.

6 Recommendations & Future Research

Due to the COVID-19 regulations, it was difficult to receive a lot of feedback regarding the practical usage of the toolkit. This caused an inability to physically interact with the social robot toolkit as the user. Due to the limitations of the given regulations, additional research will be needed, because it is important to know how effective the social robot toolkit will be when used without the COVID-19 regulations. In the future when these regulations are lifted, it is recommended to evaluate the usage of the toolkit with other groups of people who can physically interact with the toolkit. This can be done by physically sitting with them at a table or allowing them to take the toolkit home with them and interact with it for a few weeks.

The user evaluations averaged around 1.5 hours (already longer than intended), however, it seemed as this amount of time was insufficient to get the users to interact enough with the toolkit. This suggests that it is important to either schedule longer user evaluation sessions with the potential end-users, or schedule multiple shorter evaluation sessions with them.

When evaluating the toolkit, it is recommended to clearly label the components present in the toolkit. By doing so, they can evaluate the toolkit more independently, rather than having to ask the researcher to explain what a specific component is.

As mentioned in the conclusion, a programming IDE will be required to effectively test with participants that do not have experience in programming.

Additionally, it is recommended to explore possible hardware components needed to be able to develop more advanced social robots (e.g. neural network & machine learning capabilities).

Lastly, it is recommended to make one general manual that comes with an overview of the components and provides the user with links to a website containing relevant information with regards to getting the components to work.

Appendices

Appendix 1: Information brochure Research Development of Social Robot for co-design.

Background

Nowadays, the amount of robots in our society keeps increasing in terms of their role in the social domain. This results in robots not only needing to comply with industrial needs but also human-centered needs. However, it is difficult to develop humans-centered robots because humans can significantly differ from each other. A lot of human-robot developers resort to co-designing with potential end-users to develop effective social robots that fit the end-users needs. During such co-design sessions humans can get tired after long periods, which causes a decrease in overall productivity during the co-design session. This indicates great importance for the developers to be able to rapidly prototype and adjust their prototypes before productivity starts decreasing when co-designing their robots with potential end-users.

My name is Rezfan Pawirotaroeno and I am a Creative Technology bachelor student at the University of Twente. For my graduation project I would like to improve the development of social robots by increasing the efficiency in which they are prototyped through the use of a specialized social robot toolkit. Additionally I want to ensure that people from different educational backgrounds can prototype using the toolkit.

To make the best social robot toolkit possible, I would like to interview stakeholders and do user evaluations on potential end-users. The goal of the stakeholder interview is to gather additional data and feedback on the initial version of the prototype and try to find additional expectations of these stakeholders. Additionally, the goal of the end-user evaluation is to get feedback on the practical usage of the final prototype of the toolkit, from which a conclusion will be drawn regarding my thesis.

UNIVERSITY OF TWENTE.
Creative Technology

Information brochure – Social Robot Toolkit, Rezfan Pawirotaroeno s1818139

SOCIAL ROBOT TOOLKIT

This brochure contains information about the research project: *Development of a Social Robot Toolkit To Be Implemented In Co-Design and Development*

Contact researcher:

Rezfan Pawirotaroeno
email: r.z.g.pawirotaroeno@student.utwente.nl
phone: +31 647 242 266

Contact supervisors:

Edwin Dertien
email: e.dertien@utwente.nl

Robby van Delden
email: r.w.vandelden@utwente.nl

(see next page too)

Investigation Procedure

For the stakeholder, interview questionnaires will be sent out by mail to gather information and feedback on the initial version of the social robot toolkit prototype (15 mins). They will be asked questions concerning the social robot toolkit. The goal of this part of the research is to get a deeper understanding of the expectations made by the stakeholders relating to the initial version of the social robot toolkit. Additionally for the user evaluation, users will be placed in groups of 3 including the researcher. Users will be given a task to execute with the product and the researcher will collect their answers and experience (45-60 mins).

Participation

Participation in this research is completely voluntary. Participants will not be paid for their input. They can withdraw and or discontinue participation at any time without penalty. If they decline participation no one will be told and there will be no consequences for their actions.

Research activity information

During the stakeholder questionnaire, participants will be sent an email and will be asked to *digitally answer* the questions within that email. During the user evaluation participants will be placed in groups of 3 including the researcher. They will be interacting with each other *through a video call*. During this group session they will be tasked to use the social robot toolkit to develop a given robot type (45-60 mins). The 2 participants will tell the researcher what they would like to do with the toolkit and the researcher will execute their commands on the prototype which they have in front of them.

Data collection

The answers to the questionnaires will be collected. Additionally, video and audio recordings will be collected from user evaluations.

Data storage

Video and audio recordings and any additional user feedback will be encrypted using AES encryption and will store according to the AVG guidelines.

Data accessibility

Only those involved in the research may access this information. Access can be requested by emailing: Rezfan Pawirotaroeno, r.z.g.pawirotaroeno@student.utwente.nl

Data usage

The data will be used will be studied and analyzed for scientific research regarding the graduation project mentioned on the first page of this brochure. Afterward the data will be further processed within the findings of the research paper. This paper might be published on different online scientific platforms. Note that individual users' data will still be anonymous. Additionally, the processed information of the users might be used for more research purposes.

Public access to the data

Data concerning the participant or their input in the research will not be posted publicly without the permission of the participant.

Data termination

Deleting the gathered data will only be possible within a period of 24 hours after providing the data.

Additional information

For questions concerning the brochure email: Rezfan Pawirotaroeno at: r.z.g.pawirotaroeno@student.utwente.nl

For independent advice or ethical complaints, email: ethics-comm-ewi@utwente.nl

Appendix 2: Questions for stakeholder feedback (divided into sections)

Section 1 of 6

Research: Development of a Social Robot Toolkit To Be Implemented In Co-Design and Development

Information with regards to this research can be found in the information brochure. In case you have not received the information brochure or consent form, it can be requested by sending a mail to r.z.g.pawirotaroeno@student.utwente.nl.

Email address *

Valid email address

This form is collecting email addresses. Change settings

I have read the research Information Brochure given to me by the researcher and have been informed about the research project and my participation in it. In addition to this, I have read the consent form, signed it, and sent it to the researcher. *

- Yes, I have.
- No

Section 2 of 6

General information

This section will focus on the demographics of the user.

What is your gender? *

- ◯ Female
- ◯ Male
- ◯ Prefer not to say
- ◯ Other...

What is your age group? *

- ◯ 18-25
- ◯ 26-33
- ◯ 34-41
- ◯ 42-59
- ◯ 60+

What is your educational background? *

- ◯ Engineering
- ◯ Law
- ◯ Marketing
- ◯ Health
- ◯ Design
- ◯ None
- ◯ Care
- ◯ Other...

Section 3 of 6

Establishing the Frame of Mind

This section will focus on placing you in a right context. Please read the scenario described below carefully.

I have to build a Social Robot!

Imagine that for your work or education, you were tasked to build a robot that is required to interact in a certain way with a specified amount of users. However, you are not sure yet what features the robot should have, nor do you know how the robot should interact with the people.

In order to ensure that this social robot is effective/successful in their interaction with humans, you are recommended to try a co-design approach. Co-design is a well-established approach to creative practice, particularly within the public sector. In short, you will have to sit down with these specified end-users and together with them design the social robot through a series of co-design sessions. Designing this social robot with the end-users ensures to you, as the designer, that the social robot will fit the end-user needs. Additionally, it might provide insights that you as the developer were initially unaware of.

For these sessions, you decide to use a social robot construction set. This is a toolkit that comes with a different set of basic social robotic features. With this toolkit, you would be able to sit down with your co-design participants, and together with them develop a social robot prototype that fits their needs. By using this toolkit, you can add easily add or remove certain features of the prototype.

Please try to place yourself in this context, and mainly think about the social robot construction set. (What it would look like, what it can do) *

- I have read the previous part and placed my mind in the context.
- I haven't read the previous part.

Section 4 of 6

Expectations

This section will focus on exploring your expectations with regard to a social robot prototyping construction set (social robot toolkit).

Note that this research prioritizes the gathering of formative feedback, so please take your time when thinking and answering the question. Please provide as much information as possible, and do not hesitate to tailor your answers toward yourself and your personal experience. There are no wrong answers!

Would you use a social robot toolkit over going out and individually searching which hardware components you would need? *

- Yes, I prefer the toolkit first.
- No, I would not use a toolkit for building the robot prototype.
- Other...

What types of social robot prototypes do you expect to build using the social robot toolkit? (think in terms of how these robots interact with humans) *

Long answer text

What kind of hardware components do you think should be in such a toolkit for building social robot prototypes? (think about what abilities the social robot prototype should have) *

Long answer text

How do you expect to construct a prototype using the toolkit? (think about the construction/deconstruction mechanism) *

Long answer text

What is the most important feature that the toolkit should be able to provide to you as a developer that has to prototype with other people? (think about toolkit use in co-design) *

Long answer text

Section 5 of 6

Reveal and alignment

In this section a toolkit will be presented, that will be compared to your expectations of a toolkit in the previous chapter. Please analyze the social robot toolkit presented in figure 1.

Figure 1: Example social robot toolkit.

Social robot prototype toolkit description:

As seen in figure 1, the toolkit consists of a variety of different components that would enable a social robot developer to rapidly prototype social robots during a co-design session. Additionally, the components in this toolkit were chosen in a way that they would not require the developer to have a background in electrical engineering to use. In other words, it allows a lot of people to use the toolkit, no matter their educational background. Furthermore, the main controllers of the toolkit are flexible in their compatibility with a large variety of components that are not in the toolkit. This means that you would be able to add your own required components as long as they're compatible with the main controller

Does the toolkit match that which you imagined in the previous section? *

- ◯ Yes
- ◯ No

Section 6 of 6

Building on differences

This section will explore the differences of the presented social robot toolkit and your expected toolkit.

What are the major differences between your expected toolkit and the presented toolkit for making social robots? Please elaborate as much as possible. (what is missing, why would you want that) *

Long answer text

Appendix 3: User research participation consent form

Social Robot Toolkit, Rezfan Pawirotaroeno

TOESTEMMINGSVERKLARING (INFORMED CONSENT)

Participant number
(assigned by researcher): ___

Research description
This research is done by R. Pawirotaroeno as a Creative Technology bachelor graduation project at the University of Twente. The focus of this research is to develop a toolkit that can be used in the field of human-robot interaction to make robot prototyping more efficient and effective.

Project supervisor and critical observer:
dr. ir. Edwin Dertien , dr. ir. Robby van Delden

Contact information
Questions regarding this research can be sent to Rezfan Pawirotaroeno (r.z.g.pawirotaroeno@student.utwente.nl, +31 6 47 242 266). Questions regarding the ethical conduct of the research and/or complaints may be sent to the Petri de Willigen, the secretary of the ethical committee (ethics-comm-ewi@utwente.nl, Zilverling Room 1051, Drienerlolaan 5, 7522 NB Enschede, +31534892085).

Research: Social Robot Toolkit

☐ As a participant of the research I acknowledge the following:

- I acknowledge that I have been fully informed about this research project and what my role is within this research. The researcher has explained to me what their intentions are for this research and that they have given me time to ask questions.
- I acknowledge that I can stop participating in the research at any time without having to explain it to the researchers. This will not result in any consequences for me.
- I acknowledge that I have permitted the researchers to use the data I provided for this research. I acknowledge that the researchers will process the data I provided within this research in a way that I remain anonymous.
- I acknowledge that the data I provided anonymously might be published in scientific databases from which the data might be used for additional research by other researchers and I give permission for that.
- I declare that I have fully read the brochure and agree to participate in the research.

Data in the form of audio footage, video footage, and textual feedback provided by me to the researcher(s) will not be accessible publicly without my consent. Only the researchers within the project have access to the data (R. Pawirotaroeno being the main researcher). The data will be encrypted and stored according to the AVG guidelines.

☐ I allow the researchers to video record and audio record me during the interviews and answer questions regarding the research and my feedback.
☐ I agree with the way that the data is stored.
☐ I will allow the researcher to contact me for additional questions within May 2020 and July 2020.

Date:	Place: ....
Name:	Signature: ....

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