A BODY FOR R3D3

THE ROBOT RECEPTIONIST

Abstract

The R3D3 robot, Rolling Receptionist Robot with Double Dutch Dialogue, is a social receptionist robot in need of a body design. In this bachelor thesis a research is performed investigating fields of robot design practices and the participatory design methodology. The thesis puts virtual reality technology in practice to allow participants to select between 42 combinations of robot designs. The research evaluates the participants' experience in VR participatory design and qualitative results to find a body for R3D3.

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Publication date

16/07/2017

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1 Introduction

In a collaborative project, the Human Media Interaction (HMI) and the Robotics And Mechatronics (RAM) groups of the University of Twente are building the R3D3 robot. Short for Rolling Receptionist Robot with Double Dutch Dialogue. [1]

Besides the two UT groups, there are also some external partners involved in the process of development, namely software-developer VicarVision, the Dutch Police Academy, NEMO Science Museum and smartrobot.solutions.

Next to being part of the development, some of these external parties also play a role as stakeholder. [2] [3] The robot is intended to be used as a receptionist in three different environments: different types of shops (via smartrobot.solutions), large educational institutions (via Police Academy and the University of Twente) and museums (NEMO Science Museum).

Within these scenarios, it would be able to interact with individual humans, in which it would execute receptionist functions, such as pointing directions within these environments. These scenarios have a wide amount of users, including shop visitors, museum visitors and students and employees of educational institutions.

The mechatronic design and construction at the start of this thesis is done by Pascale van de Ven. [4] In this thesis, R3D3 will be given a body fitting this mechatronic skeleton, although having some slight alterations.

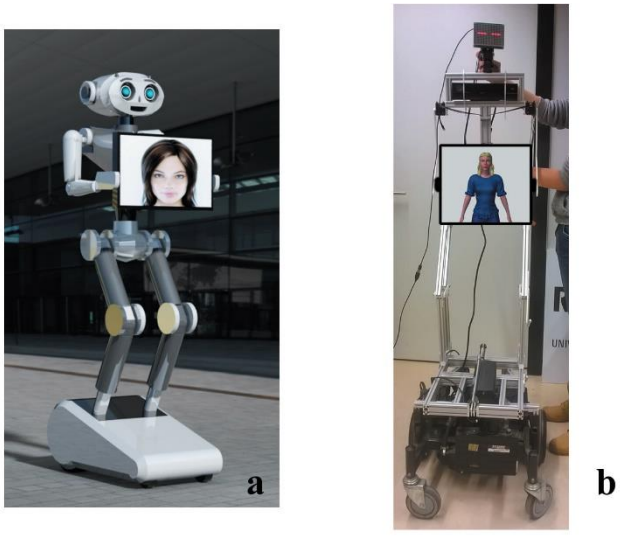


Figure 1 A conceptual rendering (A) and the current prototype (B).

1.1 Concept and realization so far

As the name suggests, the R3D3 is a receptionist robot. It's a social robot, meaning that it's meant for human interaction. Part of this concept is the fact that it consists of two entities. The first entity being the physical robot, having limited capabilities in interaction. The second entity being the screen it is carrying, on which a virtual human is displayed, able to have much richer interaction with users.

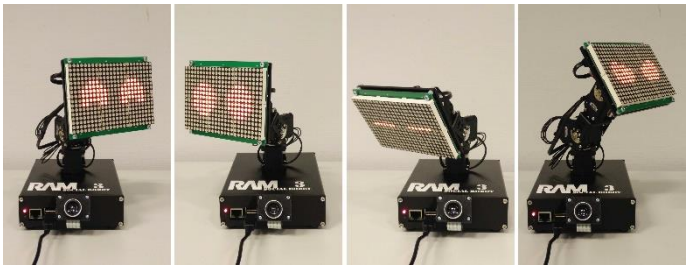


Figure 2 The EyePi system

The physical design as it is now, was designed and built by van de Ven, mainly describable as a metal skeleton out of aluminium extruded rods. Her thesis was focused on integrating the EyePi architecture within the R3D3 system.

The robot had a motorized wheelchair base, upon which a linear actuator would allow R3D3 to raise itself through its knees. Two servo motors allow the screen to be tilted. The EyePi architecture has been placed on top as the head. Finally, a Kinect is in the middle for user detection.

1.2 Adjustments made

Moving on from the thesis of van de Ven, some adjustments have been made to the skeleton by supervisor Edwin Dertien. The wheelchair base has been replaced by a regular robot wheelbase, the Kinect has been moved forward and the servos have been moved to be turning around the wrists, instead of the shoulders.

The result of these changes is that the construction has become slightly smaller in height, although the construction became more stable.

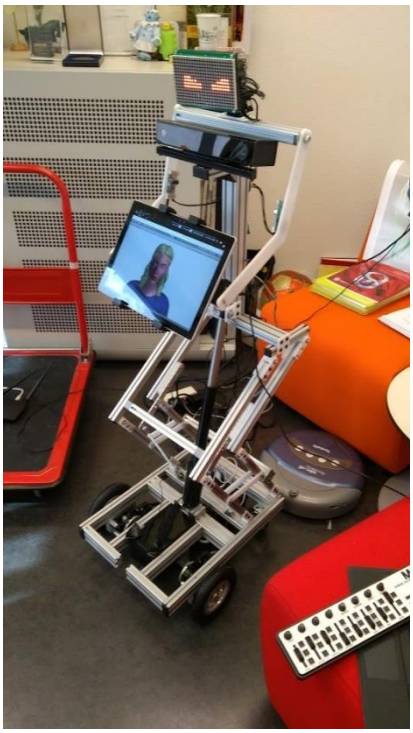


Figure 3 R3D3 skeleton upgraded

1.3 Goals and outline

With the adjustments made by Dertien, there should be no more high-profile changes to the inner structure of the R3D3, affecting the outer body. The project requires a body meeting several requirements, as stated by both external parties and internal development parties. [5]

- The body must be lightweight to minimize performance obstruction;
- The body must be designed to allow all motors to move in the programmed degrees of freedom;
- The body mustn't obstruct sensors and actuators of the R3D3 construction, such as the Kinect or its EyePi display;
- The body must be inviting for human interaction, safe to touch by users;
- The body should be easily detachable to allow maintenance.

Therefore, this research will focus on the search for a fitting body for the R3D3 project. The primary research focus in this is how a robot can look inviting for human interaction. As part of that, literature will be researched on several subjects, such as the general importance of appearance in robot design and looks at similar projects. Guidelines on making design choices will be found within the literature research, as later elaborated in State of the Art.

Based upon both the State of the Art review and the Specification, some iterations are made in Realization, with these being evaluated within Evaluation. Finally, the research concludes in both research conclusions and discussion in

2 State of the Art

The R3D3 project has a lot of similar projects, social robots, all purposed for human interaction. In this section these will be investigated, looking what their experiences contributed to the forming of the R3D3 body shell.

2.1 Background research

2.1.1 Importance of appearance

To seek what priority robot appearance has actually, this section investigates human-robot experience in local cases and cross-culturally.

Robot appearance matters, as was found out during a testing with autistic children, where they preferred a barebone robot-toy. In a research conducted by Robins et al, a test setup was made to let children interact with either a fully dressed up robot toy or a complete barebone version of the same robot toy. [6]

The results were that the children clearly preferred the barebone version. While the cause of this is not clear, it is a showcase that appearance of robotics matters a lot in further interaction. However, this is specifically aimed at autistic children, while the R3D3 project is not.

To discover whether the perception of social robots is different cross-cultural, Li et al conducted empirical tests with participants of Chinese, Korean and German background, finding a large difference between the Asian and German cultures. [7] While the Chinese and the Korean participants had similar experiences and results in these tests, the German participants had a more negative experience during these tests. The German participants had a higher awareness of the negative influences of robots than the Chinese participants did for instance. Apart from that, the Asian cultures would be classified as high-context cultures, while the German culture would be low-context. This means that the German culture is more focused on direct spoken information during interaction, while the Asian cultures are influenced by context and body language.

Religion may also result in different experience, with mainly Judeo-Christian religions having a more negative attitude towards robots. This could have to do that a robot is designed to interfere with God's work, making non-humans with human qualities,

being better than real humans, as discussed by Katz et al. [8] This could also then be tracked back to the eastern cultures having a much more positive view about robotics. Within the R3D3 project the design should reflect its awareness, to maintain accessibility for different cultures.

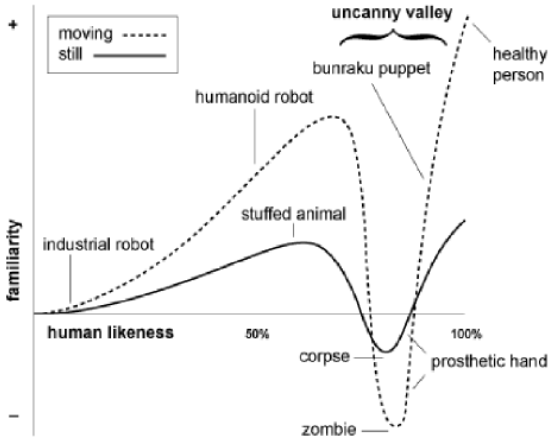
2.1.2 Related social robotics projects

Appearance of social robots is a recurring theme, inviting to see how others resolve this.

In a related project, Lee et al focused on designing and building the 'Snackbot', a robot that would deliver snacks within the University of Carnegie, where they chose for a semi-humanoid shape. [9] They had complete freedom in choosing shapes, without having to adapt their design on a pre-existent robotic skeleton.

In their study, they defined types of robot design in 4 categories: humanoid, abstract, semi-humanoid and other. In regard to the social interaction taking place with the robot, they cancelled out the abstract robots due to a lack of invitation for human interaction at an intimate level.

This decision is based upon, among others, the study of Walters et al, focussing on increase of human-like features in design until a point of uncanny valley appears. [10] (figure C) This is the point where the human-like features reach a certain level that the users feel uncomfortable in interaction.



c

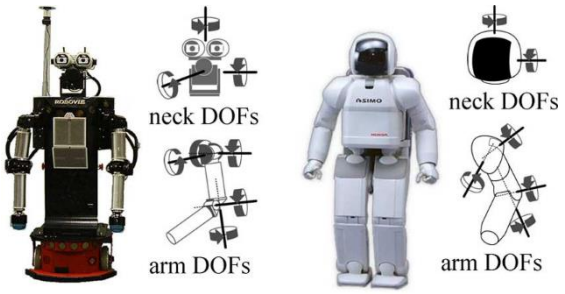
Walters et al use different categories within robot appearances, reducing it to Mechanical, Basic and Humanoid. [10] Their findings include that, up till their capabilities allowed to in their designs, a more human-like appearance is preferred by users. However, they acknowledge that their most humanoid shape did not have the same human likeness to actually have reached the point of uncanny valley. They did recognize however the left side of the graph (figure C) in their findings in familiarity.

Similarly. Syrdal et al tested how participants judge robots at zero acquaintance, again having a clear preference for the humanoid robot design. [11] Based upon emotional stability, extraversion, agreeableness, conscientiousness and intellect the humanoid robot had higher scores on all these criteria.

In the Snackbot process, they therefore decided to choose their semi-humanoid option, describing it as a combination of simple geometric forms with human cues. [9] This could be done to avoid the uncanny valley, while they also chose it for the practical reason of avoiding a mechanically complex machine.

In another research, experiences of the appearances of the Robovie and the ASIMO are compared by Kanda et al. [12] Both are humanoid robots, however their design incorporates large differences. (figure D)

The ASIMO has all its mechanical and electronical parts hidden, while the Robovie does not. The shapes of the ASIMO are also more curved, and its colouring palette is brighter.



d

During the tests, the ASIMO was a clear winner in social interaction. Participants stand closer to it, giving praise for its familiarity and novelty, while still acknowledging a feeling of safety.

However, as shown in figure d, the ASIMO has fewer degrees of freedom, meaning it has less 'muscles' to move. Even though this should result in a more abstract motion, the participants preferred it.

Humans seem more at comfort with humanoid robots, as discussed by Haring et al. [13] When asked whether the participant would allow a robot to touch him/her, the approval rating is highest with the humanoid robot. However, the effect of the uncanny valley will appear when the participants are faced with an android robot design. This being very similar to a human, the participants felt uncomfortable, and preferred rather to be touched by a very mechanical looking robot over this robot. A humanoid shape therefore seems like the best option for a new social robot.

2.1.3 Context aware design

Robots have various purposes, and they could have a different design styles based upon their purposed goal.

In contrast to the previous discussed literature, Goetz et al found out that people prefer a robot looking the way it's meant for. [14] A robot looking the way the users expect it to look, would give them better expectations the robot is capable at doing their job.

However, this literature is more dated, being released in 2003. They also acknowledge that computer technologies are not yet up to the right capabilities. The article proves to be very aware of its own early existence by calling itself an early empirical step in a longer agenda. Computer technology in 2017 allows much more mobility than in 2003, ruling out some limitations of then.

2.1.4 Anthropomorphic features

Looking at (semi-)humanoid design, some human features may not be included in robot design to avoid this 'uncanny valley'. The design research by DiSalvo et al focuses on this topic, focussing on humanoid robot heads. [15]

Suggested is that, as well suggested by Goetz et al [14], there should be a balance between the robot-ness and the human-ness. This is one of the core issues recurring in this literature research; humanoid may only be up till a point. Disalvo et al propose the following 6 suggestions in humanoid robotic head design.

Wide head, wide eyes Unlike a human, the robot head should by wider than its tall. **Features that dominate the face** Proportionally, the design should emphasise the features from the eye brow line till the mouth, while reducing the proportions of the rest. **Complexity and detail in the eyes** There should be some complexity in the eyes, emphasizing them and projecting humanness.	**Four or more features** The awareness of features, such as a nose, eyes and mouth, greatly contribute to the perception of humanness. **Skin** Not a bit of mechanical substructure or electronical component should be shown, and so a skin is necessary. This may be of soft or hard material. **Humanistic form language** The shapes should be organic, with more complex curves in the forehead, back head and cheek areas.

2.1.5 Colour

Part of the visual appealing characteristics is the perception of colouring within robotic design, where a majority of white robots can be perceived. This is also one of the reasons Kanda et al proposed this to be of preference to users, reasoning that also due to

this colouring scheme users preferred the ASIMO over the Robovie. [12] In a similar reasoning, the Snackbot was designed with a primarily grey colour, with orange highlights. Suggested by Lee et al is that orange is related to food and restaurants in U.S. culture. [9]

Within literature, the perception of colours is often linked with evoking emotions and moods. MacDonald covers the use of colour within computer graphics. While not being product language, there are some clear associations mentioned in this article. [16] These being the following.

Color	Positive Associations	Negative Associations
Red	Passion, strength, energy, heat, love	Blood, war, fire, danger, anger, aggression
Green	Nature, spring, fertility, safety, environment	Inexperience, decay, envy, misfortune
Yellow	Sun, summer, gold, harvest, optimism	Cowardice, treason, hazard, illness, folly
Blue	Sky, sea, stability, peace, unity, depth	Depression, obscenity, conservatism, passivity
White	Snow, purity, peace, cleanliness, innocence	Cold, clinical, surrender, sterility, death, banality
Gray	Intelligence, dignity, restraint, maturity	Shadow, concrete, drabness, boredom
Black	Coal, power, formality, depth, solidity, style	Fear, void, night, secrecy, evil, anonymity

Figure 4 Common color associations as mentioned by MacDonald [16]

2.2 Problem statement

Robots designed for human interaction require a well-designed outside as well. Overall, literature is often categorizing robot designs in categories as for instance mechanical, basic and humanoid. For social interaction, there is a very clear preference for humanoid design.

However, this is up till a point where the robots look too similar to humans, and users will feel uncomfortable. The effect of familiarity will be reversed immediately, and social interaction will be disturbed. This is the infamous uncanny valley taking place.

There are also some different interpretations per culture as well, and mostly there's a difference between Western and Eastern cultures. Low-context cultures are more intrigued by direct interaction, while high-context cultures are very much more aware of the appearance.

And while some give clear suggestions of what (not) to include in a design, there is not an exact recipe for the perfect robot design. The ASIMO and Robovie, for instance, are each carefully designed, but have very varying experiences by users.

The R3D3 therefore requires a design in which all discussed literature can be taken in mind, also adapting to its own characteristic double entity concept. In the end, the design needs to be inviting for user interaction.

3 Specification

The R3D3 project is designed for human interaction. Therefore, the body should be as inviting as possible. As was stated in State of the Art, there is a clear preference to humanoid shaped robots. To test this theory, a range of designs should be made and tested along with users.

3.1 Design Methodology

There are a lot of design methodologies, some focused on industrial applications, some on educational applications, and sometimes both. Tomiyama et al discuss a large amount of them, while classifying them in the following table. [17]

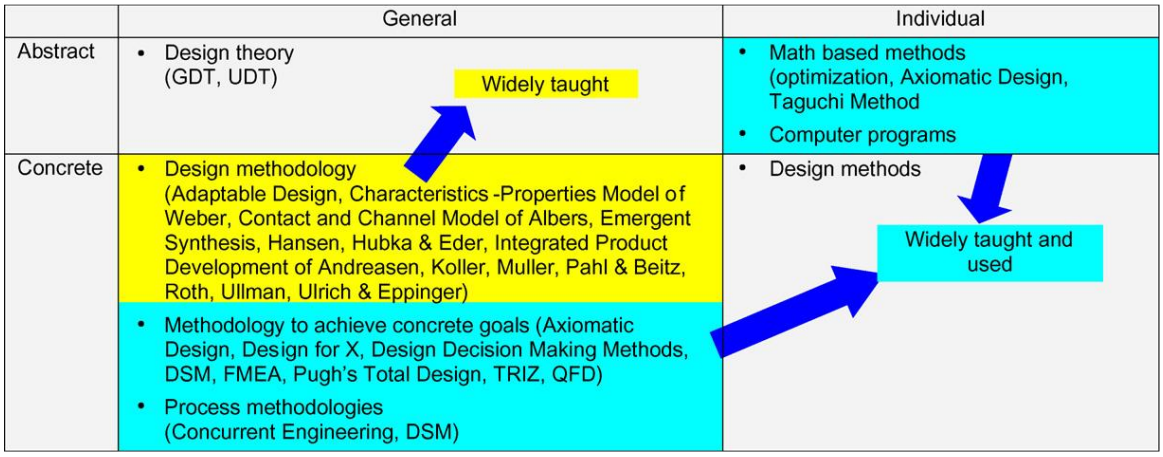


Figure 5 DTM widely taught and widely used according to Tomiyama et al [17]

Within this project, a general methodology is required, with the project having concrete goals. This results in a reduction of the amount of possible design methodologies according to Tomiyama et al to 8. Namely; Axiomatic Design, Design for X, Design Decision Making Methods, DSM, FMEA, Pugh's Total Design, TRIZ, and QFD.

However, these methods allow for design in a more broader perspective; complete development of a project. For instance, one of the mentioned design methodologies, Pugh's Total Design is a very large system which allows users to take note of all sorts of influences in a design process. Within this research these methods would however be largely redundant due to the low amount of objectively recognizable influences.

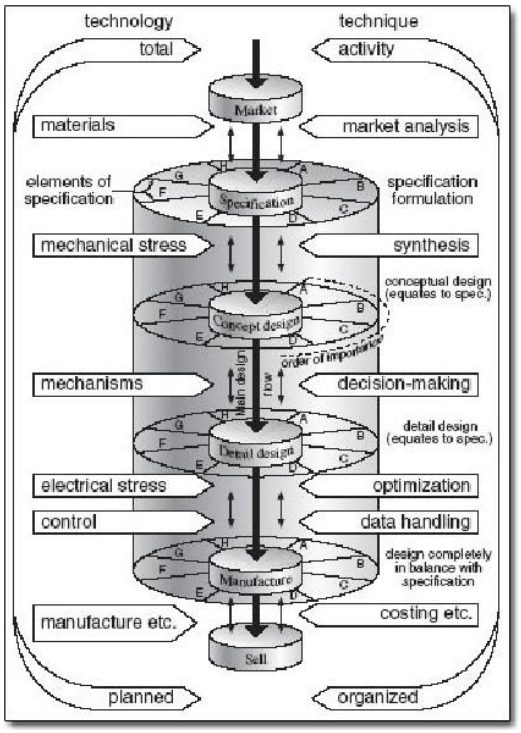


Figure 6 Push's Total Design [16]

Therefore, a different minimalistic design methodology is required. A wish from both state of the art research as introductory text is to integrate user inclusion. Therefore, the choice was made to investigate participatory design methodology. Wilkinson et al discuss using this methodology in a commercial setup. [18] One of the arguments is as well to use this for better user inclusion, as its countereffect is demonstrated in figure 7.

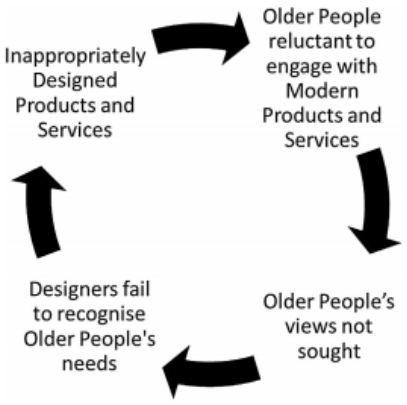


Figure 7 User exclusion due to designer oversight [15]

Another reason to do is to attract 'experts'; participants who have used a similar system before. An argument for the R3D3 robot could be to attract users familiar with robots for instance.

Generally, the participatory design method is based on gathering qualitative data rather than quantitative data. Wilkinson et al suggest using the following:

- Surveys taken with participants;
- Semi-structured interviews with participants;
- Observational research in a controlled environment.

With this thesis focusing rather on the research topics than on producing the design, the option was chosen to select the participatory design methodology.

3.2 Requirements

To align the available design options and abilities, a requirements list is setup according to the MoSCoW prioritization technique. [19] The participatory design group would be executing a test in a test environment, in which different design possibilities are available. There are several requirements for this realization.

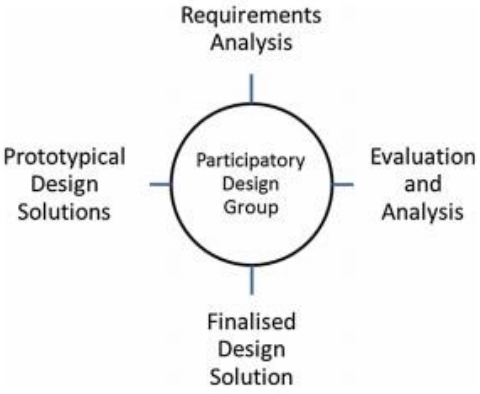


Figure 8 The ideal spot for the participatory design group in a design process [15]

Must

- Allow swapping of multiple body and head designs by participants
- Allow further commenting/influence by participants
- Allow simple instruction for participants to execute the test

Should

- Show context in which the R3D3 robot could be used
- Not distract users from their main goal

Could

- Allow the use of multiple colours
- Show multiple contexts of the R3D3 robot
- Simulate/execute the virtual human
- Simulate/execute the full mechatronic functionality

Won't

- Allow multiple participants at a time

4 Realization

In this part the realization of different designs for a body for R3D3 is discussed. A first attempt was done at producing this in a design workshop, while later this was continued in a VR environment. Since the R3D3 project in general was at an end, a physical body was constructed for demonstration purposes by supervisor Edwin Dertien. This body is briefly described as well.

4.1 Phase 1: Physical materials

During the first phase of the realization phase, an attempt was done at covering the robot in easily formable materials such as extruded polystyrene foam. Ideally different models would be constructed, so users could switch between different foam models of different parts.

Figure 9 R3D3 covered in foam parts

Instead however, due to inexperience in working with this material it wasn't possible to produce a full covering design within a reasonable amount of time, and soon after a different approach was sought to test multiple designs.

However, the foam did allow for some experimental work, and did result in at least covering up the upper body and the wheel base. This means that covered parts include:

1. Chest
2. Waist
3. Shoulders
4. Arms
5. Hands
6. Wheelbase

A physical appearance of R3D3 was however required for demonstration purposes of the entire project. Therefore, supervisor Edwin Dertien kept the arms and adapted various IKEA products and other simple materials into this version of R3D3 as it was demonstrated at various conferences. This appearance is later on modelled within phase 2 as well.

Figure 10 R3D3's final physical appearance

4.2 Phase 2: Virtual Reality Environment

Within this stage, a virtual reality level is constructed in which different designs are made for the R3D3 robot. The choice for a virtual reality environment was made in the following reasoning:

1. Ability to place the designs in context of different user scenarios;
2. Ability to rapidly produce a variety of designs, both in shaping, styling and colouring;
3. Immerge participants realistically;
4. Eventually simulate robot performance

To realize this, a virtual reality environment is constructed within the Unity Game Engine, in which models made using Autodesk Maya are imported. Finally, a HTC Vive is used as virtual reality device.

4.2.1 Context

Universality of the robot design is important as stated within the requirements of this research. Therefore, a simple contextual environment was designed to place the R3D3 robot in. As mentioned, one of the user cases would be R3D3 functioning as a host/receptionist within a museum, such as the NEMO science museum. [1] Therefore, a small exhibition is modelled in which the R3D3 could be placed, which could be part of a bigger museum.

The exhibition consists of both photographic material and three-dimensional objects. The size of the real-life testing room did not allow full physical movement through the exhibition. To focus on the designs, the maximum space was set to the blue rectangle as seen in figure 8. Further screenshots of the environment are available in Appendix 8.2: VR-Environment.

Figure 11 The virtual museum

4.2.2 Designs

Within the virtual reality environment, the R3D3 robot skeleton was modelled as a basis. From there on, users of the VR environment are able to switch to different body and head shapes.

Figure 12 R3D3 Robot Skeleton as presented in the VR Environment

The environment also accommodates users to change the colours of the body shape and head shape independently of each other. To ease the technical challenges of constructing this environment, the colours were limited to predefined colours. Respectively these are red, orange, yellow, green, blue, purple, pink, white, grey and black. Additionally, there is also a transparent material added. All of

these materials are stylized to look like vacuum formable ABS plastic, as this is chosen as one of the options most suitable for production of a design.

The shapes are made fitting in different design spaces. In similar projects and other state of the art research, humanoid shapes were clearly preferred in interaction. However, within this research a very context-aware effect is tested.

The designs are not ordered, to avoid any way of steering direction by doing so. The designs have the following description:

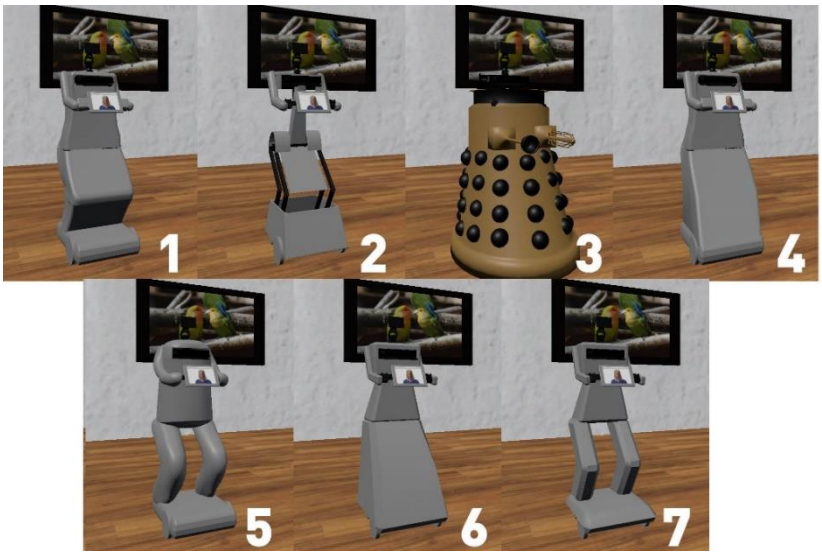


Figure 13 The body designs as presented in the VR environment

1. Acts as an inbetweener for options 5 and 6, combining rounded shaping with a more angular silhouette.
2. The most open and industrial looking option, defined by sharp corners, open areas showing parts of the robot. Based upon the real life produced version by Edwin Dertien.
3. The Dalek design from the British TV series Doctor Who. This design was included to see whether people would like to be guided by a popular TV-character.
4. Model 1 with a 'skirt' to completely cover the legs.
5. The most rounded and humanoid shaped design for the R3D3 skeleton, having rounded legs for the mechanical lifting.
6. Following a humanoid silhouette, while having a very stiff and angular shape. Edges have 45° bevels.
7. Model 6 with 'legs' instead of a skirt covering the mechanical lifting.

The head designs had similarly different designs as well, some very rounded and following guide rules as mentioned in the state of the art research, while some abandon these. Mainly these designs integrate the EyePi Matrix screen, and with this in mind a couple of designs were created.

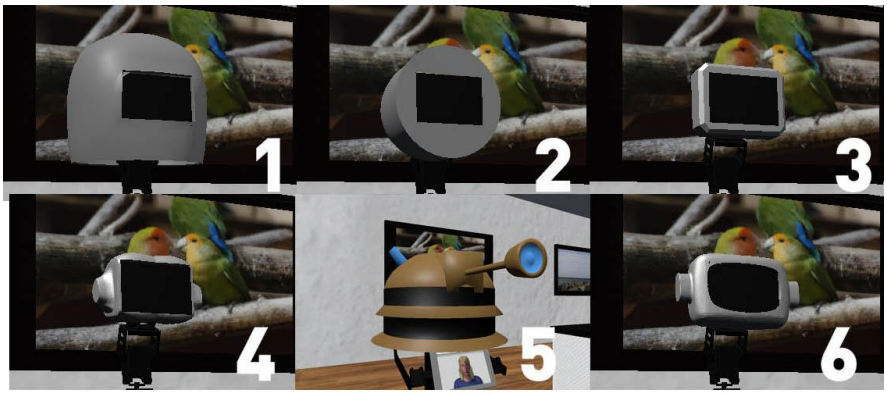


Figure 14 The head designs as presented in the VR environment

1. A rounded helmet shape
2. Based upon an IKEA lamp shade, this design is also based upon the real life produced version by Edwin Dertien.
3. The industrial answer to designing a head; a minimalistic border around the EyePi screen with a slight 45° bevel.
4. Rounded shapes, providing ears for the head.
5. The Dalek TV-character, as also mentioned in body 3.
6. An in-between option between heads 3 and 4, including rounded shaping while also providing ears.

4.2.3 Technical setup

As mentioned, the chosen VR-headset is the HTC Vive. This was chosen practically; being the available equipment at the University, but also because the Vive allows users to physically move in virtual environments. An example would be the drawing in figure 12.

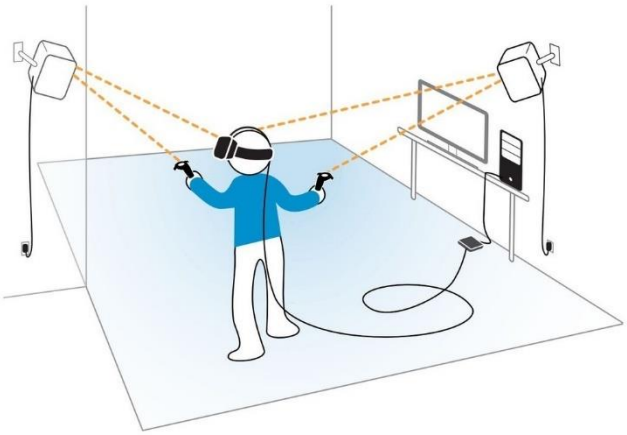


Figure 15 An use case of the HTC Vive [15]

Ideally, the provided handheld controllers would be used to control the design-process. These where however, for reasons unknown, not functional in the Unity Game Engine within the time of realization. Therefore, an alternative was sought by using a wireless mouse.

A C# script, when triggered, switches between different game objects within this environment. This triggering is done by either the left mouse button (body models) or the right mouse button (head models).

Another C# script, when triggered, cycles through different materials within the environment. This triggering is done by either scrolling up (Body colour) or by scrolling down (Head colour).

Figure 17 Hierarchy of different R3D3 designs within Unity

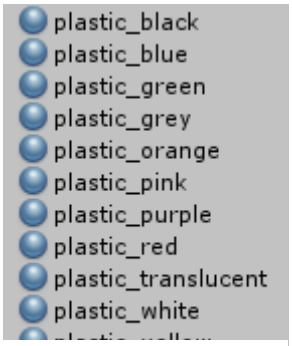


Figure 16 Hierarchy of available materials within Unity

The environment would not have a start or end state while being used, thus the user could decide for themselves when they are starting and finished with their work.

5 Evaluation

The VR-environment was tested amongst 10 participants, all being Creative Technology students ranging from 18-25 years old. These participants were instructed, both verbally and through the instruction/consent form, to design a robot they found fitting. (appendix 8.3: Informed consent & instruction form). They were not given instructions on what they had to have in mind while performing this task.

After they felt they were done, participants could take off the VR headset and where consequentially asked to fill in an online questionnaire. An exported version can be found in appendix 8.4: Questionnaire. Full results of this questionnaire can also be found in the appendix, namely appendix 8.5: Evaluation results. Within this chapter, some of the findings will be discussed.

5.1 Participants' choices in design

For full overview of the results, see Appendix 8.5: Evaluation results.

One of the main questions were what combination of head/body styling and colouring the participants have chosen. Due to the background and number of participants, the results cannot be deemed as significant to conclude for all the user groups of the R3D3 project by picking a design. While the research allows brief exploration of a select group of potential users of the R3D3 system, the primary focus of this research is to explore what priorities participants had and what universality a design could have for this sort of robot.

Looking at what shapes and colours were chosen, there is no majority found in the body shapes. Two of the selected body shapes were based off each other. Combined, these were chosen by 4 out of 10 participants. These body shapes, however, were not the most rounded shape; these were bodies number 6 and 7.

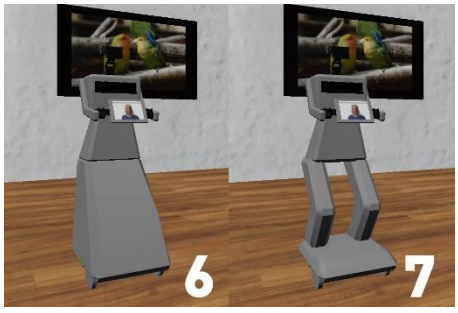


Figure 18 Body shapes 6 and 7

The head has a clear majority, where 5 out of 10 participants chose head number 1. The closest follow

Figure 19 Head shapes 1 and 3

up was head number 3, which carried 2 out of 10 participants' choice.

Finally, the colours chosen by participants were mainly grayscale colours, with heads having more variety in the different other colours. While several cases in the state of the art review suggested that electronics should be as invisible as possible, the transparent casing was often chosen as well by participants.

5.2 Participants' justification in design choices

Participants were able to give open comments within the survey and test, and these explained some of the results as seen from the test. Mostly these comments and other results gave insight in the universality of their design choices.

One of the given comments, as repeated by several participants, is that they did chose the transparent material because this would be ideal if it were to be used in a museum related to technology or science. The design would then blend in as part of the exhibition, instead of an aiding entity.

This reasoning of participants is also seen when asked how well their design would fit in the following public spaces; NEMO Science Museum, the Rijksmuseum, the Police Academy and the University of Twente. A majority of the participants agreed that their design would fit excellently in the NEMO Science Museum ($\bar{x} = 3{,}9, s = 1{,}14$), while having mixed response whether it would fit in the classic art Rijksmuseum ($\bar{x} = 2{,}6, s = 1{,}20$). The University of Twente and Police Academy had the same results measured over the participants, being positive about possible use of their design in these facilities. ($\bar{x} = 3{,}8, s = 1{,}17$) Notable in observational research was that most participants were familiar with the NEMO Science Museum, the University of Twente and the Rijksmuseum, while they were more distant and doubtful when picking their options for the Police Academy.n

One participant had several critical comments about the R3D3 project in general, and on both mechatronic and styling design grounds. This participant found that the mechatronic work was too much focused on making a humanoid shaped skeleton on wheels, while feeling that this does not help in interaction. The participant also suggested that the robot appearance is strongly dependent on the user scenario.

The available head and body shapes were therefore also criticized by this participant, for not having shapes that diverge from the robot skeleton to try entirely different

concepts. Other participants were more positive about the amount of body shapes available ($\bar{x} = 3{,}6, s = 1{,}11$), while the number of head shapes could have been more satisfied ($\bar{x} = 3{,}1, s = 1{,}22$). Some participants found that there could have been very different head shapes as well, feeling that the current ones available are not distinct enough.

Participants did feel that there were enough hues of colours available ($\bar{x} = 3{,}9, s = 1{,}37$), but some commented that they'd have liked some tones and shades in the available colours. Besides that, they would have also liked to change the colours of body shape 3 and head shape 5.

When asked about priorities in choosing their design, 7 participants found it to be important to find a fitting combination in body and head design, followed up by 5 participants also listing looking for personal connection with the design as an option.

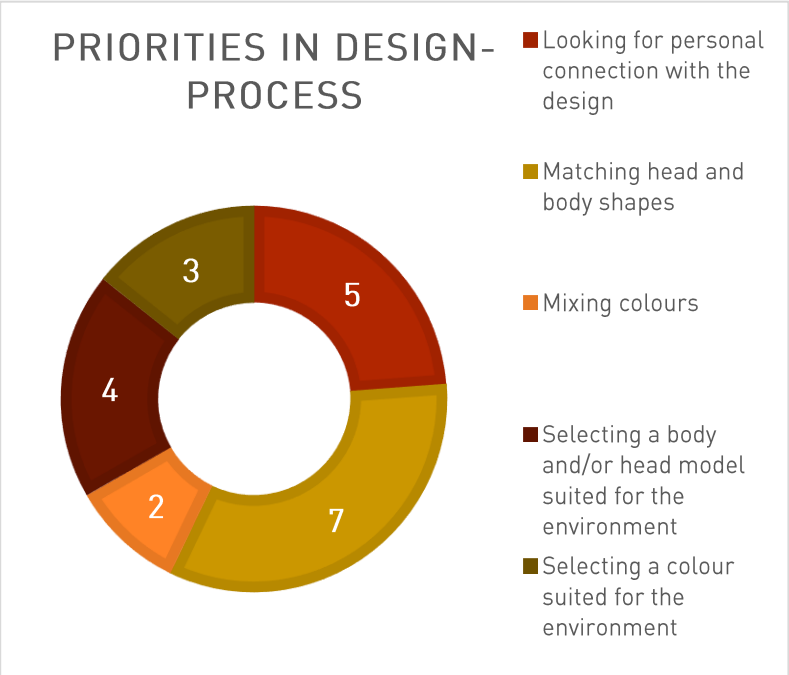


Figure 20 Numbers in chart represent amount participants prioritizing this

One participant found that, because of the name 'R3D3' he was also prioritizing looking for a more technical, science fiction look robot.

5.3 Participants Virtual Reality Experience

As mentioned, the participants are college students, ranging from 18-25 years old. In this research the HTC Vive was used to test the designs. Since this technology is relative new to the mass, this experience could be different from a real life experience with the designs. This could be from either being a trending technique to it not giving a clear vision of the designs.

Therefore, 6 statements were added to the survey, on which participants could assign rating of agreement. Users largely agreed that it however was of added value in their

experience ($\bar{x} = 4{,}2, s = 0{,}60$) while still deeming the environment as a realistic area where R3D3 would be used in real life. ($\bar{x} = 4{,}3, s = 0{,}46$) The participants would be interested in visiting the environment themselves, were it real. ($\bar{x} = 3{,}9, s = 1{,}14$)

It being an added value according to the participants, they also felt immersed by it ($\bar{x} = 4{,}1, s = 0{,}70$). They also felt that this level of engagement could not have been achieved on a regular display screen. ($\bar{x} = 4{,}1, s = 0{,}46$) Some users used the VR-headset before, while others had a first time using it. Even though some were unfamiliar, participants felt largely respected while executing this test. ($\bar{x} = 4{,}3, s = 1{,}27$)

6 Conclusion

6.1 Research conclusions

This research started with the goal to build a body for R3D3, while finding out what it takes to make a robot design inviting. While the time did not allow a physical design to be produced, there's enough to answer this research question. This was done by conducting a participatory design experiment along with 10 college students.

First, the state of the art research emphasized how a majority in various tests of robotics prefer humanoid shaped robots, with bright colours. What is endangering however, is the uncanny valley; the moment a robot becomes too much humanlike. In this case the interaction between human and robot is severely damaged, on a level that even a simple mechatronic construction would've worked better.

In this research this theory was tested again, mostly to gain looks in the mindset of participatory designers. Concluding is that in this case, the most humanoid shape did not achieve a majority. Notable is that this is amongst 10 participants, and should not be noted as significant to judge that. Resulting is however that, going back to the research question, participants had varying opinions and priorities in choosing between the available designs.

Commonly participants found that for instance colouring is very context-dependent; in a science museum a transparent robot, showcasing all the working mechatronics, would be ideal to make it as a part of the exhibitions. Contrary, they would find that their own designs were rarely good for a classical art museum such as the Rijksmuseum, in which it would conflict with surroundings.

Concludingly, there is therefore no universal answer for inducing user interaction; the guidelines, as given, could be wrong for some contexts. Specifically for the R3D3 project, it could also assist to have the physical domain non-humanoid looking, so there is a clear distinction between the virtual human and the physical construction.

6.2 Discussion

Styling and design isn't like mathematics; there are not a sum of formulas that will make everything good to look at in a scientific method. While design is recognized more

and more within academics, there's still a large amount of subjectivity connected to the subject. The benefit in this research of having a participatory group of 10 college students is that they are also critical thinkers; while they do submit to be willing to visit a real life environment with R3D3 in it. They are therefore part of the user group, while also having ideas and knowledge in what they find important in this design process.

The state of the art would deny several aspects of the body shell as produced by Edwin Dertien for the robot; the research would disapprove of it showing a large amount of mechatronic work. Nevertheless, the body was selected three times, and the head once. This could for instance be due to the nature of the participants, being technical students in favour of seeing the nature of the machine.

While the test environment did not achieve all the requirements, it did achieve its 'Must' factors. Participants did feel that several 'Could' factors would have added functionality. This would be factors as testing in multiple virtual environments and having a richer amount of shapes and colours.

Using the participatory design methodology, combined with a virtual reality environment, benefitted the qualitative data within this research. The virtual reality environment allowed the researcher for rapid producing of various models, but the mainly allowing for projection of these designs within a user scenario. Users found this of added value, and this promises to be useful to rapidly observe multiple 3d imageries of designs, without having to use rapid prototyping machines.

7 Future Work

There are several aspects of this research which could be expanded, these will briefly be discussed. Notable however is that the R3D3 project has officially ended as of July 2017, and these suggestions are therefore written to expand a similar research.

Enhancement of virtual environment

The virtual environment was rapidly constructed to simulate the robot designs. However, there are several improvements possible to enhance the simulation. These include:

- Improve realism of environment
- Simulate the R3D3 or other robot system
- Allow multiple scenarios
- Include AI visitors
- Allow interactive menu control for selecting models/colours
- Allow colour scales
- Include the HTC Vive tracked controllers
- Include ambient sound
- Include a survey within the environment

Expanding of virtual environment

As some participants mentioned, the content should be expanded to include more models and colours suiting the needs of the participants.

Pop cultural characters

None of the participants had chosen for the Dalek character, while one participants prioritized selecting a body fitting sci-fi themes such as in Star Wars, due to the name R3D3. It could be that, because of the familiarity users have with pop cultural characters such as from various sci-fi movies and television series.

In addition, this could eventually mean that users would have a higher level of familiarity with this robot and thus better interaction, while not being a humanoid shape such as the uncanny valley theory would implicite.

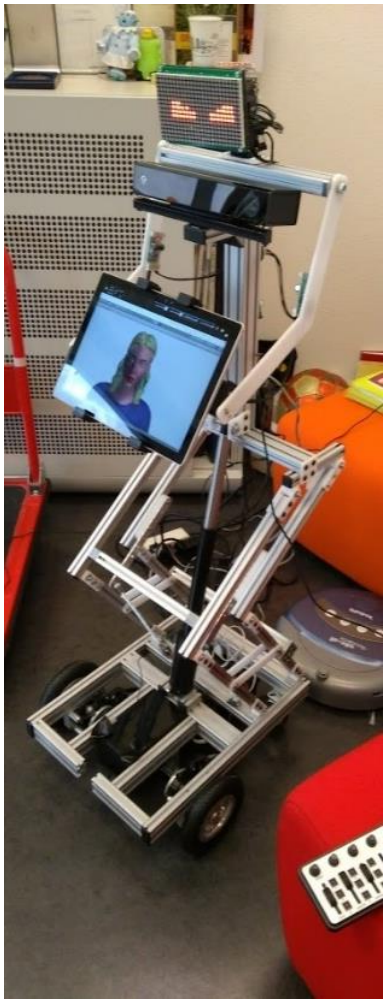
Production of designs, real life testing

Physically produce the designs as well and perform similar tests in real life to measure how well the virtual and the real world correlate in results. While this is in most likeness not possible with the R3D3 project anymore, the hyping of the VR technology can be tested in other future work.

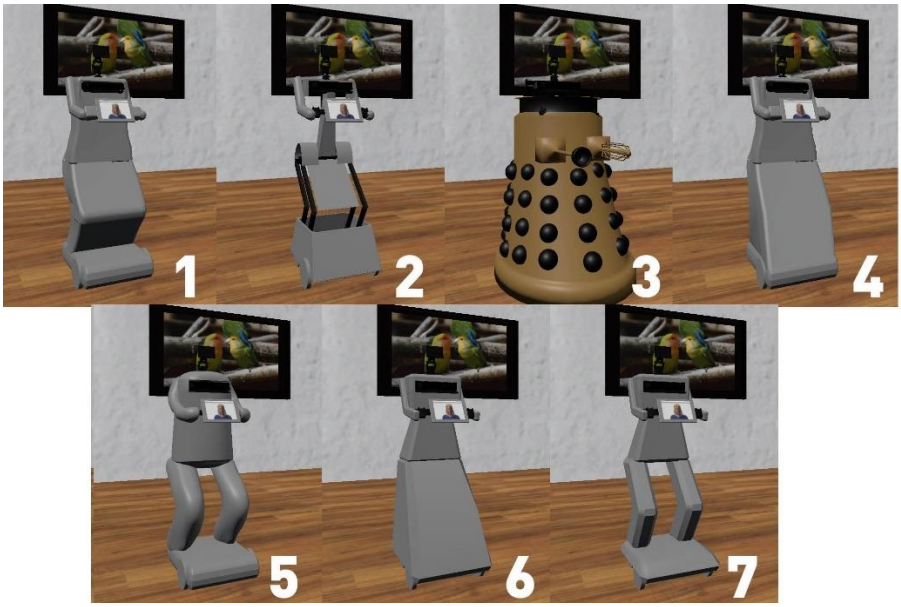
8 Appendix

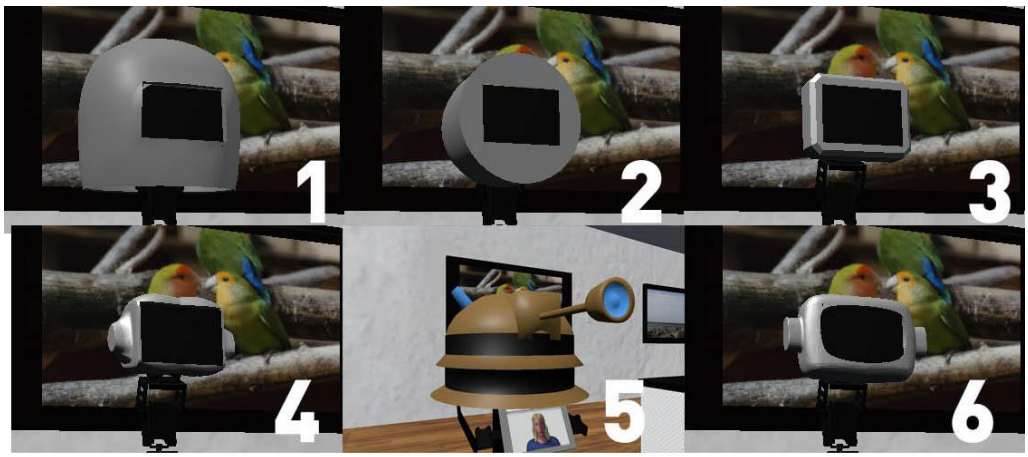
8.1 R3D3 Photos

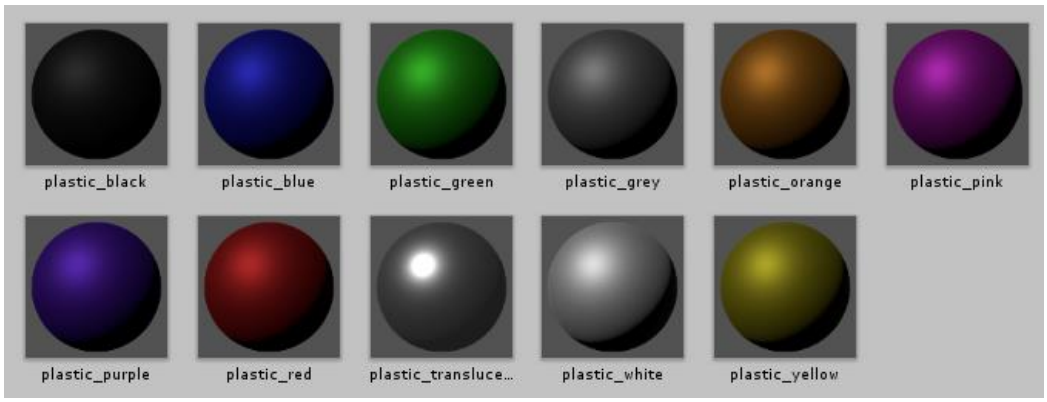
8.1.1 Physical transformation



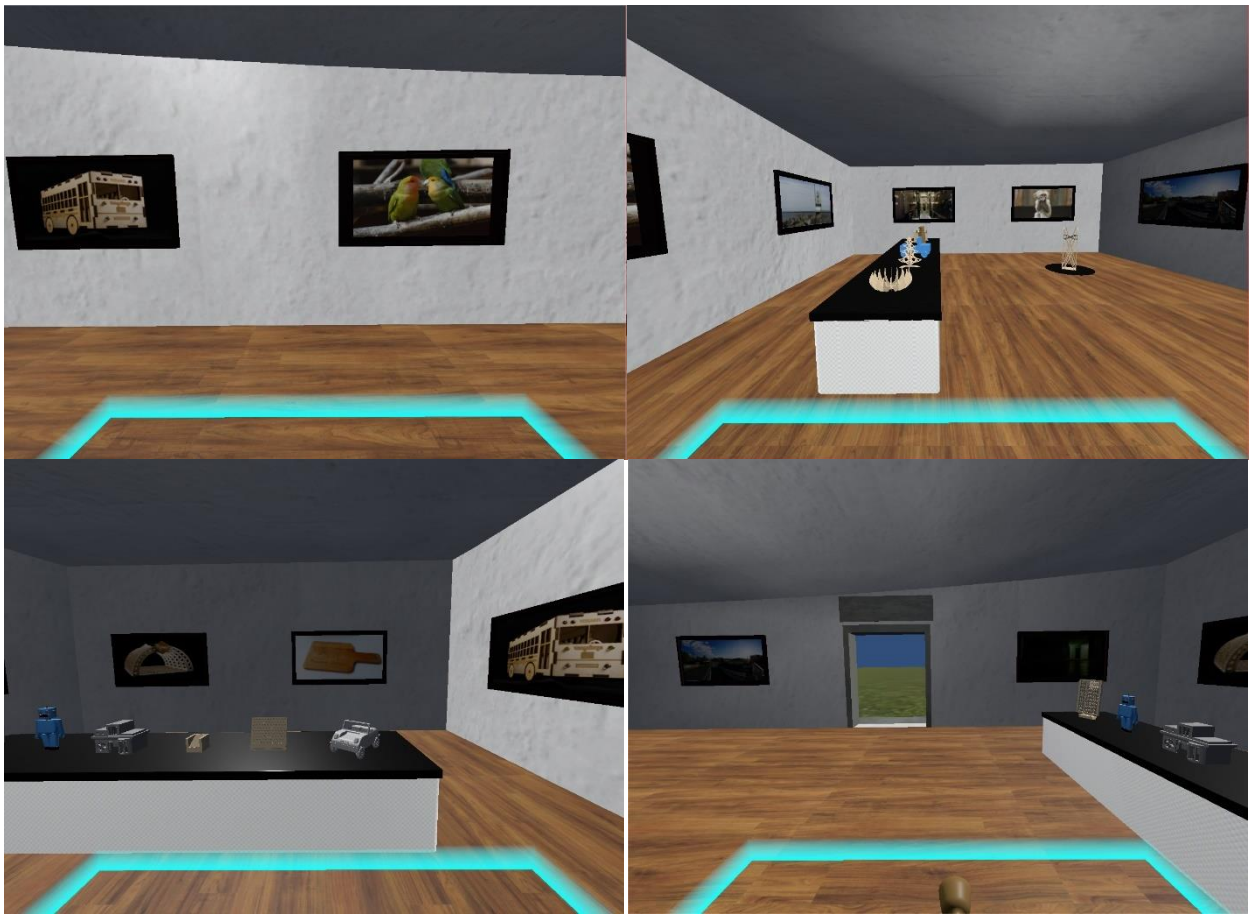
8.1.2 VR-Models







8.2 VR-Environment



8.3 Informed consent & instruction form

The Robot Experience

Aim of the research: design a body for the robot through participatory design.
Researcher: Robin van Emmerloot

In the upcoming experiment, you will find yourself in a virtual modern art museum.

Within this museum, a robot skeleton called R3D3 is placed. This is the rolling receptionist robot, acting as a host/receptionist within this museum.

Objective: select a fitting body and head for this robot.

Controls:

- Left Mouse button: Change Body
- Right Mouse button: Change Head
- Scroll up: Change Body colour
- Scroll down: Change Head colour

After selecting a combination, the VR headset may be removed and the user will kindly be requested to fill a questionnaire. In-depth questions may be asked by the researcher, users are not obligated to answer these.

All questionnaires and feedback will be processed anonymously. Experiments are not being recorded visually or audibly. Time will be recorded.

During any moment of the experiment you are free to stop. The experiment is on full voluntary base. By exiting preliminary your test-results and will not be saved. Any personal work is not affected by the experiment.

'I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the provided information above. My questions have been answered to my satisfaction. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. My liver will not be affected by this experiment. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission. If I request further information about the research, now or in the future, I may contact Robin van Emmerloot.'

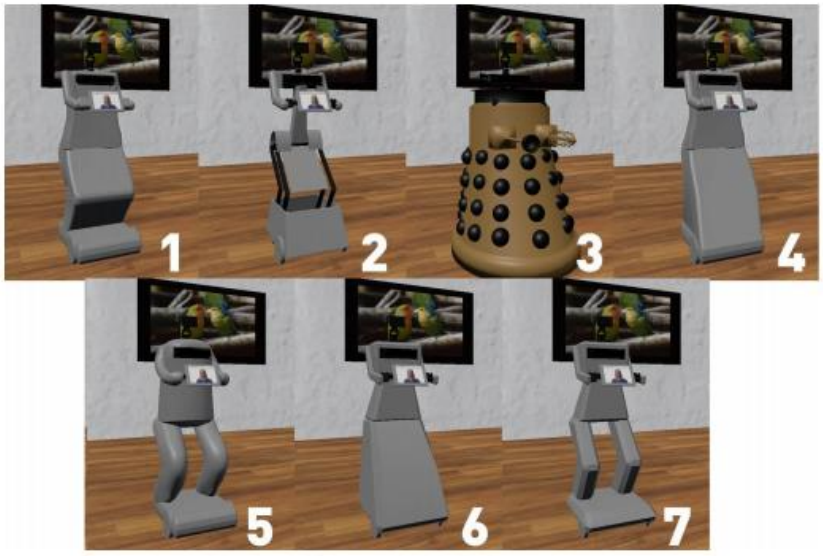
Participant: name	Signature	Date
_____	_____	_____

'I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.'

Researcher: name	Signature	Date
Robin van Emmerloot	_____	_____

8.4 Questionnaire

Note: Due to automatic localization, some of the additional info is exported in Dutch. During the evaluation however this was presented in English.

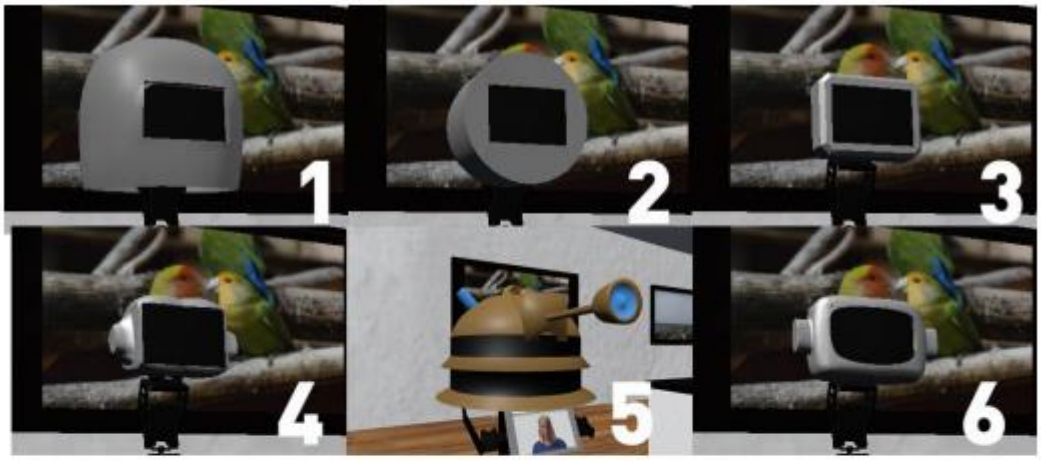


1. **I selected this body shape.** *
Markeer slechts één ovaal.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7

2. **I selected this colour for the body.** *
Markeer slechts één ovaal.

- ◯ Red
- ◯ Orange
- ◯ Yellow
- ◯ Green
- ◯ Blue
- ◯ Purple
- ◯ Pink
- ◯ White
- ◯ Grey
- ◯ Black
- ◯ Transparant



3. **I selected this head shape.** *
Markeer slechts één ovaal.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6

4. **I selected this colour for the head.** *
Markeer slechts één ovaal.

- ◯ Red
- ◯ Orange
- ◯ Yellow
- ◯ Green
- ◯ Blue
- ◯ Purple
- ◯ Pink
- ◯ White
- ◯ Grey
- ◯ Black
- ◯ Transparant

Design

Questions regarding your design choices.

5. **My priorities in choosing the design were...** *
   Vink alle toepasselijke opties aan.

   - [ ] Selecting a body and/or head model suited for the environment
   - [ ] Selecting a colour suited for the environment
   - [ ] Matching head and body shapes
   - [ ] Mixing colours
   - [ ] Looking for personal connection with the design
   - [ ] Anders: _____

6. **Within the NEMO Science Museum, my design would also fit.** *
   Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

7. **Within the Rijksmuseum, my design would also fit.** *
   Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

8. **Within the police academy, my design would also fit.** *
   Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

9. **Within the University of Twente, my design would also fit.** *
   Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

10. **Comments**

_____

VR-Simulation

Questions regarding the VR environment.

11. **There were enough body shapes available to make my own design.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

12. **There were enough head shapes available to make my own design.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

13. **If not, briefly describe what body/head shape you missed.**

_____

14. **There were enough colours available to make my own design.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

15. **If not, briefly describe what colour you missed.**

_____

_____

_____

_____

_____

16. **The VR-Environment was of added value in this test.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

17. **The VR-Environment seems as a realistic area for the R3D3 robot.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

18. **I would visit the environment in real life if this were possible.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

19. **On a regular display-screen I would have felt the same engagement within the environment.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

20. **I felt immersed by the environment.** *
Markeer slechts één ovaal.

	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

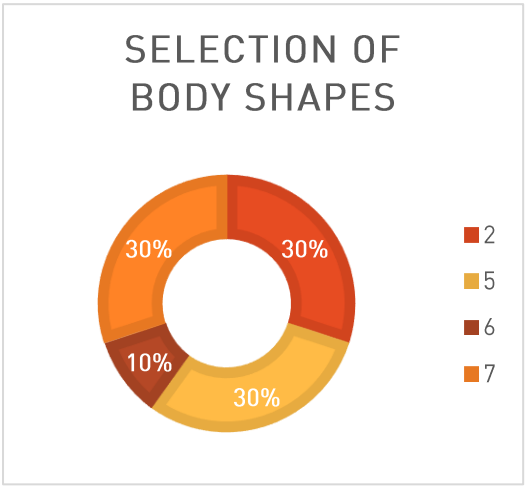
21. **I felt respected while executing this test.** *
Markeer slechts één ovaal.

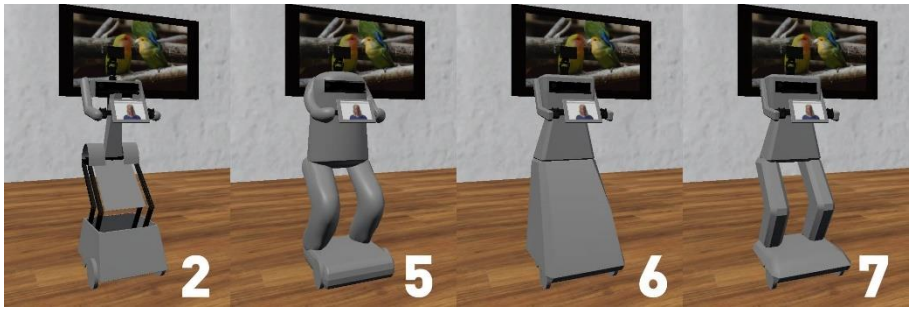
	1	2	3	4	5	
Disagree	◯	◯	◯	◯	◯	Agree

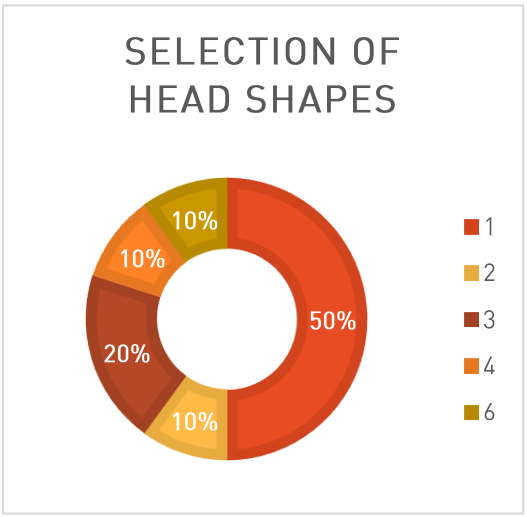
22. **Final remarks**

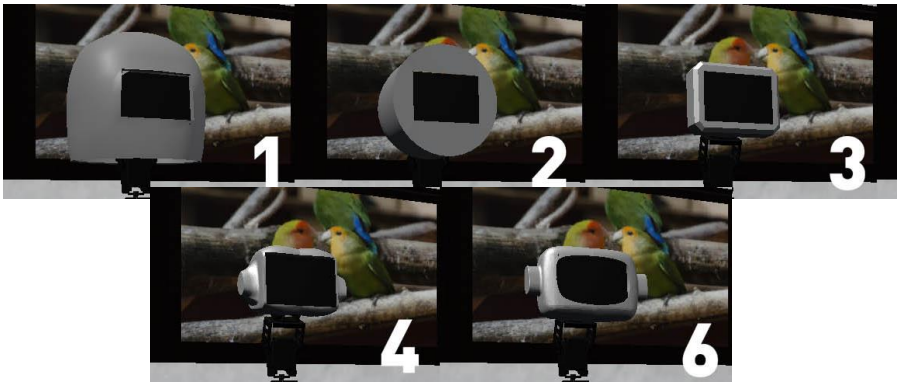
8.5 Evaluation results

8.5.1 Selection of shapes

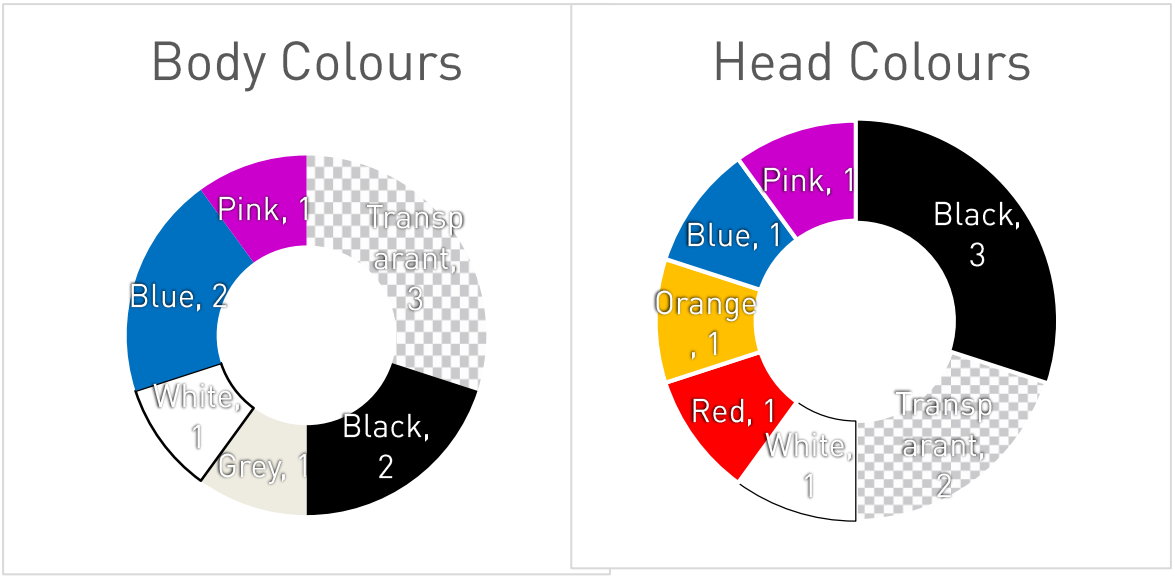




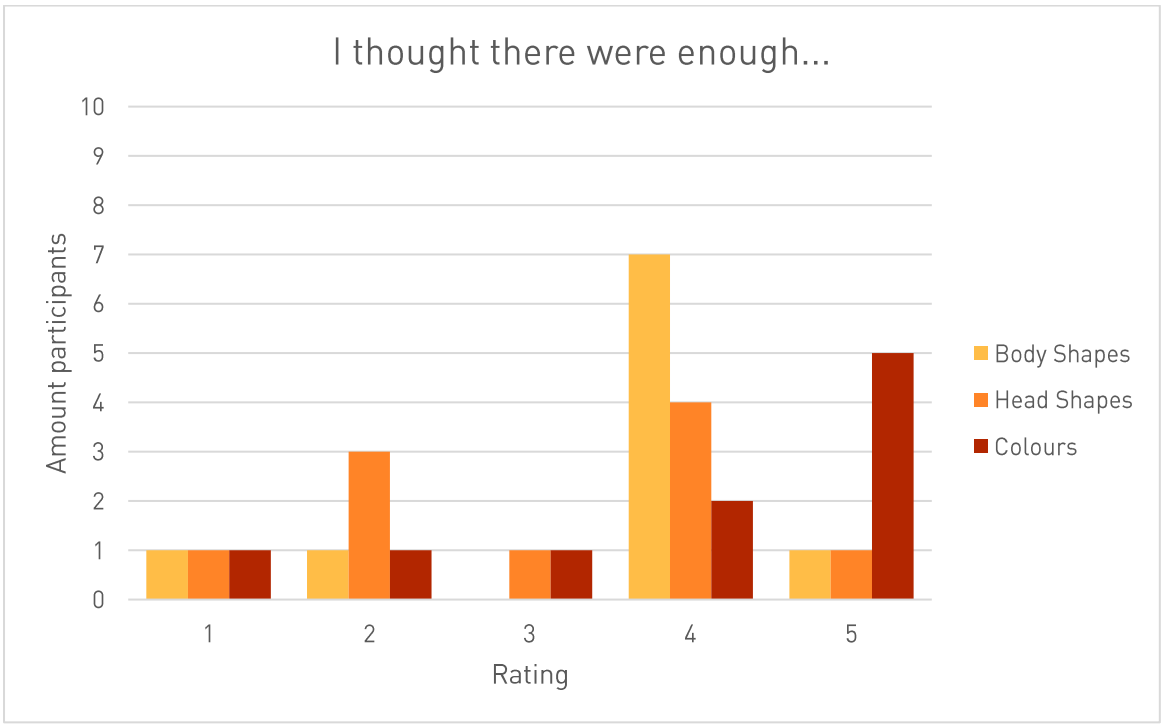




8.5.2 Selection of colours



8.5.3 Rating of available shapes and colours



8.5.3.1 Comments on shapes

Each quote is from a different evaluation.

- 'Everything my mind could come up with. I want all the options. Unlimited power and such!'
- 'More different shapes, because some of them just looked like a version of the previous one'
- 'I missed a bigger head'

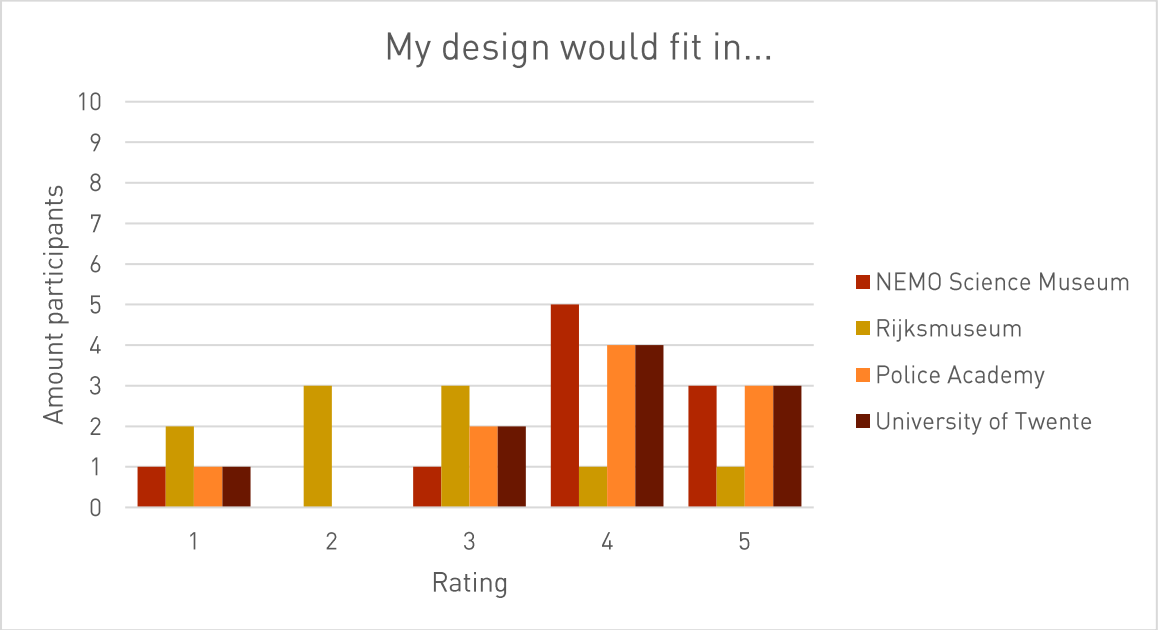
- 'I missed fundamentally different designs like, no legs and no head.'
- 'It was difficult to see the shape of the head, because the first colour did not stand out to the frame itself'

8.5.3.2 Comments on colours

Each quote is from a different evaluation.

- 'I missed that you could not change the colour of body number 3 and head number 5'
- 'I missed a brighter white.'
- 'All colours were very vibrant. I would have liked some dimmer options'

8.5.4 Rating of Design Universality

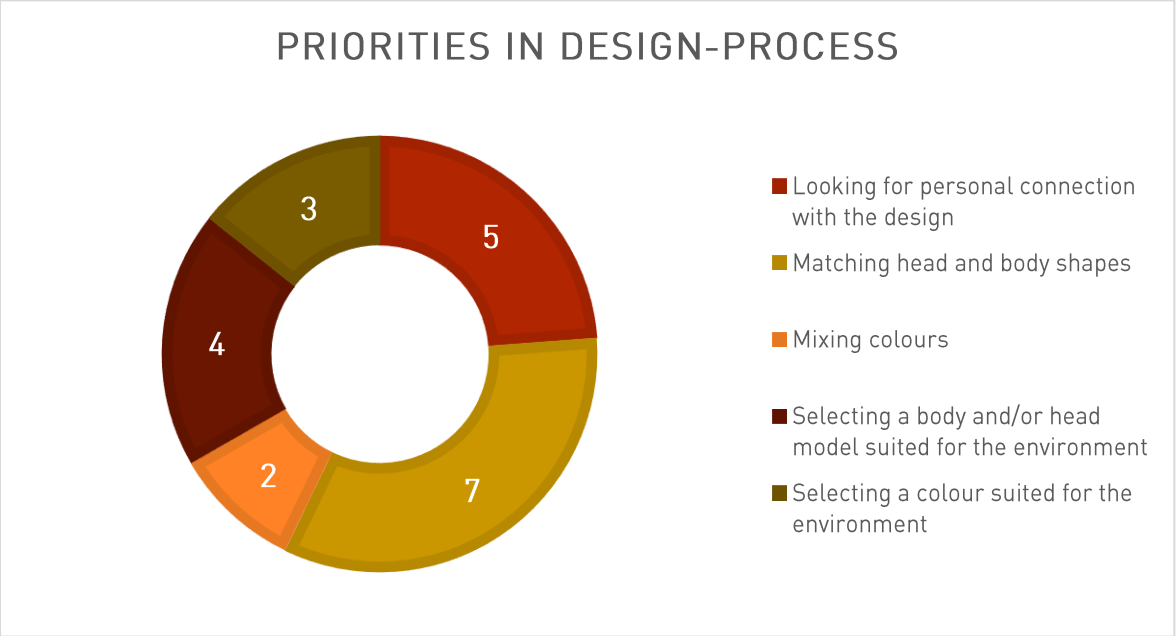


8.5.4.1 Comments on Design Universality

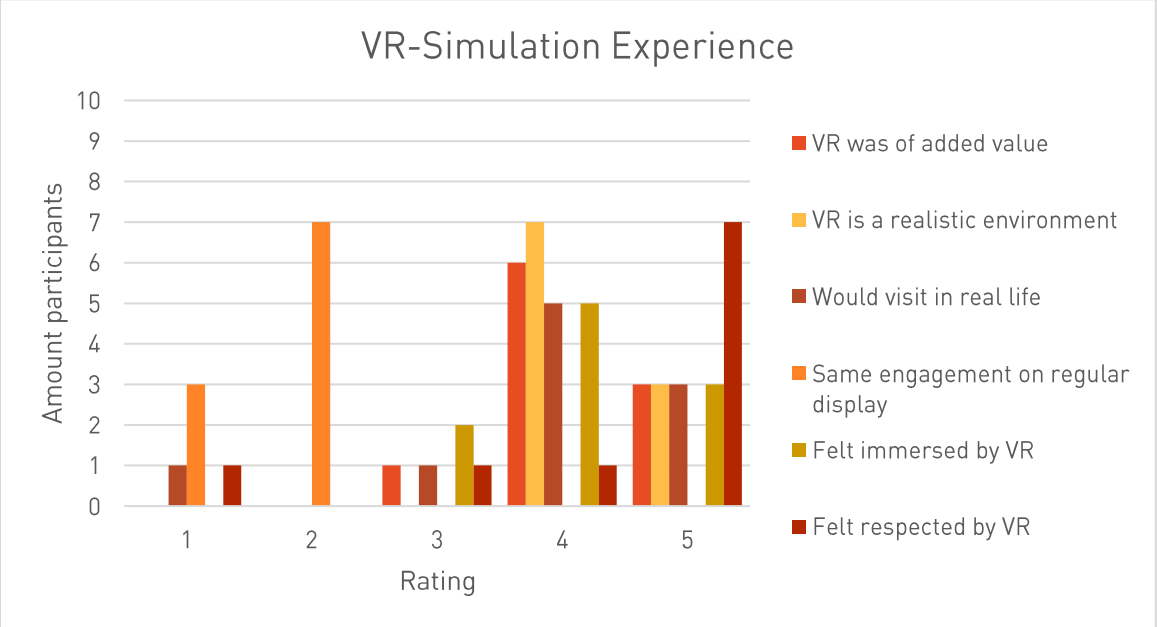
Each quote is from a different evaluation.

- 'I think that for the more technical museums the transparent color works very well, as it shows the inner workings of the robot. For the Rijksmuseum or the Police Academy, I would use a different color scheme.'
- 'The appearance of the robot color wise is strongly dependant on the context of the machine. All situations above can have better tailored design than seen in the simulation. The chosen design was the best looking design in my opinion. I would however opt for rounder edges instead of the bevel edges. The entire design however seems to much inspired on the human body slammed on wheels. I think it would be wise to make a HMI robot based on interaction instead of Mechanics.'

8.5.5 Priorities in design process



8.5.6 Rating of VR Experience



8.5.7 General comments

Each quote is from a different evaluation.

- 'the black colour looks more like dark grey'
- 'Maybe adding multiple scenes and comparing the different designs people make for these scenes would be an interesting follow up research.'
- 'I do not think that robots like this have a future in the entertainment industry or any other form of human interaction benefit in the long term.'
- 'I felt like i was standing in the floor of the museum'
- 'Because of the 'R3D3' name, I was aiming for a more sci-fi looking robot'

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