I, ROBOT

Mind perception in the real world

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Mind perception in the real world.

A Social Neuroscience thesis project

Supervised by Dr. Ruud Hortensius

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Abstract

In contrast to prior beliefs, the perception of minds does not occur along a single continuum. Researchers Gray, Gray and Wegner (2007) proposed that mind perception is based on two distinct dimensions. These dimensions are agency and experience. Experience involves hunger, fear, pain, pleasure, rage, desire, personality, consciousness, pride, embarrassment, and joy. The other dimension is agency, which involves among other things self-control, morality, memory, emotion recognition, planning, communication, and thought. Studying these concepts is important since mind perception is closely tied to moral decision-making. The aim of this current exploratory study was to investigate if more information about robots would change the perception of people's own minds in a social context. The idea is based on the notion that what is defined as the 'self ' does not exist in a vacuum but is influenced by the social space. The research question that was aimed to answer with this study was: "Can changes in robot mind perception change people's own mind perception and control of behaviour?". Seventy-six participants completed the experimental procedure, starting with the Social Technological Network task and the Diffusion of Responsibility task, then either an intentional or a mechanical knowledge manipulation followed. Afterwards the two tasks were repeated. For the Social Technological Network task changes in robot mind perception did not significantly influence mind perception of self. There was no significant effect found on behaviour either. The effects did all move in the right direction of what was expected, meaning that the significance might be found with an altered research design. Taking concepts like embodiment, human uniqueness and anthropomorphism into account could be fruitful for further research.

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1. Introduction

1.1. Perceiving minds

The notion that most living things have brains seems to be common knowledge. Mice have brains; dogs have brains; apes have brains; babies have brains; grandparents have brains. There is, however, a difference between having a brain and having a mind. The brain is an organ, that can be seen and even touched. The mind is something that is subjectively perceived. Making this distinction begs questions such as, who can we hold accountable for their actions? If a mouse steals food from a supermarket multiple times, they will not be held accountable, yet employees most likely will be. This example clearly illustrates how the perception of different minds can lead to distinct decision-making behaviour. The concept of mind perception is important because it determines if someone (or something) can be held accountable for their actions and whether they (or it) have moral worth. This is not only true for other's and their minds, but it also holds up for the self. Thus, the perception of our own minds and the minds of others shape the way we interact and make decisions.

1.2. Dimensions of mind perception

In contrast to prior beliefs, the perception of minds does not occur along a single continuum. Researchers Gray, Gray and Wegner (2007) proposed that mind perception is based on two distinct dimensions. This idea is a product of a study they did in which participants had to fill out a survey, making pairwise comparisons of different characters, such as robots, dogs, and old ladies. They had to compare these characters on mental capacities (e.g., ability to feel pain) and personal judgements (e.g., "which character do you like more''). So, for example, one such comparison involved rating whether a five-year-old girl is, more able to or less able to feel pain than a chimpanzee. The outcome of this study was that mind perception happens along two dimensions, agency, and experience. Experience as defined by Gray, Gray and Wegner (2007) involves hunger, fear, pain, pleasure, rage, desire, personality, consciousness, pride, embarrassment, and joy. The other dimension is agency, which involves among other things self-control, morality, memory, emotion recognition, planning, communication, and thought. Some of the statements from this 2007 study relate to agency as well as experience, and characters that scored high on these statements are seen as to have 'more' mind and were more valued. Moreover, a correlation was found between agency and experience for liking a character, wanting to save it from destruction, wanting to make it happy, and perceiving it as having a soul (Gray, Gray and Wegner, 2007). However, moral judgements show differing correlations with the two dimensions. Agency is linked to moral agency and hence to responsibility. For example, in case of punishment for wrongdoing (e.g., "A grandma killed someone vs. a toddler stabbed someone, which one do you think would be more deserving of punishment?"). In contrast, experience is linked to moral patience and hence to rights and privileges. For example, the desire to avoid harming (e.g., "If you were forced to harm a dog or a robot, which one would it be more painful for you to harm?"). These different perceptions of mind thus capture different aspects of morality.

1.3. Perception of Artificial Minds

In a on the *uncanny valley* Gray, Gray and Wegner (2011) used the two-dimensional mind perception paradigm to investigate how humans perceive the hypothetical minds of robots, introducing them as a new category of characters. Doing research on the minds we attribute to robots is becoming more relevant since robots are starting to play a quite prominent role in western society. In a study by Stafford and colleagues (2013), older people in a retirement village were invited to use a prototype robot with healthcare functions over a two-week period. Residents were told that the robot could take vital signs (e.g., blood pressure), remind them about their medication, make telephone calls, play some songs, and play memory games. Participants could use the robot as much as they liked in during the two-week period. The authors found that people who chose to use the robot held more positive attitudes towards robots and attributed less agency to robots. The amount of mind agency and mind experience the residents perceived in robots also predicted how much robot-users intended to use the robot again. One possible explanation for these findings is that elderly people who believe that robots are high in agency are more afraid of interacting with them. These ideas may originate from exposure to robots in media, in which the capabilities and possible dangers of robots are often exaggerated. Overall, the outcome of this study supports the theory by Gray, Gray and Wegner (2011), that robots have a higher capacity for agency than for experience.

Both the study by Stafford and Colleagues (2013) and the study by Gray, Gray and Wegner (2011) show that humans can indeed attribute a mind to a robot. However, there is what researchers call an 'experience gap', humans are perceived to have significantly more experience than robots and other machines. This is interesting given that the ascribed experience is often seen as an essential human quality. Gray, Gray and Wegner (2011) also state this in their *uncanny valley* study, that experience, but not agency, is seen as fundamental to humans. They suggest that experience is what is fundamentally lacking in robots and machines (Gray, Gray and Wegner, 2011).

1.4. Self-perception

This study focusses on the relationship between the mind perception of other agents and the mind perception of the self. How can the mind perception of robots change the perception of the self? And are these changes in self-perception reflected in our behaviour? These questions are based on a set of complex concepts. The concept of 'self' for instance has an entire multidimensional field of research dedicated to defining it. According to previous cross-cultural research, the self is most reliably described when a person shows a motivated response to information from the social environment. Motivated responses should thus depend on how the self is defined in a social space (Graupmann, 2018). This show the complexity of the concept of the self, it does not exist in a vacuum, but it is shaped and influenced by the social environment. This somewhat fluid self can thus change according to the information of the social environment, which makes it logical to assume this same principle holds up for the perception of the self and thus the mind.

Ferrari, Paladino and Jetten (2016), studied whether social robots pose a threat to human distinctiveness. They based their research on the notion that the introduction of social robots into society might pose a threat to human identity. In their article these authors propose that this threat might stem from too much perceived similarity between social robots and humans. The blurring of the boundaries between humans and machines is perceived as damaging to humans as a group, which could alter the human identity (2016). This 2016 study was mainly focused on investigating how the visual appearance of different robots can pose a threat to human identity, but the effect of mind attribution was investigated as well. Ferrari, Paladino and Jetten (2016), found that the type of robot affects the amount of agency and experience attributed to it. However, the attribution of mind did not influence the perceived damage a robot can do to human identity. Thus, the attribution of mind can pose a threat to the human identity but only if the robot in question is visually similar to humans. Even though the attribution of a mind did not directly threaten human distinctiveness, the attribution of mind to certain robots can indeed be seen as a threat. As stated by Ferrari, Paladino and Jetten, too much similarity between humans and other agents can blur certain identity boundaries. As stated, before the self is shaped and influenced by our social environment. Robots are becoming a part of this environment and when they are too similar to humans, visually as well as in terms of mind perception, they can threaten human uniqueness. Interacting with social robots might thus shape the self and the perception of the self.

In the previous section it was noted that robots are rated as high in agency, therefore they are intentional beings that control their actions. The attribution of intentional agency to others such as other people, animals or robots has an influence on fundamental mechanisms of cognition (e.g., perspective taking or attention) (Zwickel, 2009; Wiese, et al., 2012). It remains unclear whether the attribution of intentional agency to others also affects our own sense of agency. Sense of agency constitutes a crucial aspect of the human mind. The sense of agency describes the feeling that one is in control over one's actions and their consequences. Ciardo and colleagues (2020) investigated this sense of agency. They stated that sense of agency is influenced by social contexts and thus the presence of other agents, like robots. Previous studies have shown that in the presence of others the sense of agency is reduced (Beyer, et al., 2018). Moreover, in their study Ciardo and colleagues (2020), investigated whether the presence of an embodied robot would reduce sense of agency in a Diffusion of Responsibility task. This Diffusion of Responsibility task consisted of the performance of costly actions (i.e., losing various amounts of points) to stop an inflating balloon from bursting in both individual and joint tasks (i.e., with the Cozmo robot or with an air pump). Participants also had to rate the perceived control they felt over their actions. Ciardo and colleagues (2020) found that in conditions where the robot was able to interact (but did not) participants perceived lower sense of agency for the social robot even after a successful trial. Together the results suggest that interacting with social robotic agents affects sense of agency, similarly, to interacting with other humans.

1.5. Intentional or mechanical view

In the previously discussed study by Ciardo and colleagues (2020) social robots are seen as intentional agents that can, for example, follow your eye gaze. In contrast, the air pump used in the same study cannot follow people's eye gaze. Participants, therefore, view the air pump as mechanical. However, the context might also play a role in the perception of robots. A study by Bulter and colleagues (2019) focused on the effect of social context on perception of robots. They found that robots are perceived higher in mind perception in a robot context, so between other robots, then in a human context. They also found that regardless of context, robots were always rated lower than humans for mind perception. Yet another study focused on a different aspect for robots' mind perception: function. The study of Wang and Krumhuber (2018) focused on robots' original functionality: economic or social. They found that robots with high social abilities were rated as high in emotional experience but lower in cognitive ability (related to agency). In contrast, robots that were built to achieve economic efficiency and financial profits were rated as higher in cognitive ability and lower in emotional experience.

These studies illustrate that the mind perception of robots (social or not social) is dynamic and context dependent. However, this can also be used to the advantage of science. For example, a study by Bossi and colleagues (2020) investigated mind perception of social robots in a test of mind perception (Instance Test). In this test the participants are asked to decide between two descriptions of the depicted scenario: one being a more mentalistic description such as "the robot is cheating" and the other being a more mechanical description such as "the robot is unbalanced". They used resting state EEG as a predictor of view and found that resting state EEG beta-activity differentiated people who were later inclined towards interpreting robot behaviour as either mechanical or intentional. This pattern is similar to the pattern of activity in the default mode network, which was previously demonstrated to have a social role (Frith, 2007). Previous research found that activation of the default mode network is also related to the attribution of the intentional stance to humans (Spunt et al., 2015).

Besides predicting the perception that someone has of the mind perception of a robot, in experimental research participants can also be primed with a certain type of mind perception. This is because humans tend to anthropomorphize others, for example when seeing cars as 'having a face' or when perceive crates in the moon as the 'man in the moon'. In the study by Wiese and colleagues (2017) the authors state that non-human agents have the potential to trigger mind perception, as long as they display observable signs of intentionality, such as human-like appearance and/or behaviour.

1.6. Aim of this study

The aim of this current exploratory study was to investigate if more information about robots would change the perception of people's own minds in a social context. The research question that was aimed to answer with this study was: "Can changes in robot mind perception change people's own mind perception and control of behaviour?". To investigate this question, the ratings of the Social-Technological Network task were compared for the perception of the social robot Cozmo and for the self, both on agency and experience. But, besides Cozmo, ratings of mind perception of other humans, media and robots were measured as well. Next to perception, behavioural control was analysed as well. Furthermore, it was assessed whether changes in perception would lead to changes in behaviour in a Diffusion of Responsibility task. In this behavioural task both agency and experience were measured.

2. Methods

2.1 Data Accessibility Statement

The data that was analysed in this study was collected online. All measurements, manipulations, data exclusions and sample size determination rule are reported. Data and code are publicly available on the OSF website.

2.2. Participants

The participants for this study were selected through a convenience sample (e.g., through social media platforms from the authors) and through the recruitment program SONA. The total number of participants was seventy-six with the mean age of 26.7 (*SD = 11.8; Min = 18.0; Max = 65.0*). An independent samples t-test was done to establish if the variance in age was equal between the two conditioned groups. The mean age of the mechanical condition group was 26.38 (*SD= 11.54*) and that of the intentional condition group 27.36 (*SD = 13.05*). No significant difference between the two groups was found when looking at the age distribution ($p = 0.882$, $t(74) = -0.149$). Of the seventy-six participants, 48 were female, 27 were male and one participant left this question blank. A Chi-squared test showed that there was no significant difference between the distribution of gender with a p-value of 0.774. The mechanical condition group consisted of 14 males and 23 females, the intentional condition group consisted of 13 males and 25 females. Participants rated their previous exposure to electronica and other items: robots, smartphones, virtual assistants, smart watches, and internet of things (IoT) on a 1-7 Likert scale. A score of 1 indicates no use at all and a score of 7 indicates daily use. Participants indicated the highest use of smartphones with a mean score of 6.8 (*SD = 0,6*), followed by IoT with a mean score of 6.4 (*SD = 1.3*). Virtual assistants scored the mean of 2.4 (*SD = 1.7*) and smartwatches scored the mean of 2.1 (*SD = 2.1)*. Robots were used the least and scored a mean of 1.9 (*SD = 1.4*). An independent samples t-test was done to establish the variance of the amount of exposure among the two conditions. This test showed there was no significant difference between the two groups for all categories. All categories have p-values above 0.05, IoT ($p = 0.29$, $t = 1.06$), robots ($p = 0.367$, $t(74) = -0.90$), smartphones ($p = 0.72$, $t = 0.36$), Smart Watches ($p = 0.07$, $t(74) = -1.85$) and virtual assistants ($p = 0.15$, $t(74) = -1.45$). In the mechanical group the standard deviations were as follows; IoT (*SD* = 0.87), robots (*SD* = 1.65), smartphones (*SD* = 0.68), smart watches (*SD* = 1.58) and virtual assistants (*SD* = 1.563). For the intentional condition the exposure standard deviations were IoT (*SD* = 1.54), robots (SD = 1.24), smartphones (*SD* =0.60), virtual assistants (*SD* = 1.53).

Participants needed access to the internet and a computer or phone to complete the experiment. Before taking part in the experiment, the participants were briefed about the procedure and the duration of the experiment. They digitally signed an informed consent form, stating that they agree to the terms of participation and are aware that they can drop out at any given moment. After the experiment the participants were probed for suspicion about the goal of the research. The participants that guessed the aim of the study would be excluded from the data to eliminate possible compromised data. However, none of the participants guessed the aim of the study.

2.3. Experimental design

In this study within-subject design was used. The dependent variable in this study will be the final ratings in the Social-Technological Network task and the anxiety/control felt during the final Diffusion of Responsibility task. The independent variable in this study will be the knowledge manipulation. Participants will be randomly assigned to either the mechanical or the intentional knowledge manipulation. For this experiment the amount of exposure to technology could influence the results. Therefore, the levels of exposure to technology of the participants will be measured as a control variable.

2.4. Social Technological Network task

The experiments in this study were programmed in the online experiment builder Gorilla. The Social-Technological Network task was used to establish ratings of the dimensions of mind perception agency and experience. This task was originally designed by Gray, Gray, & Wegner (2007) as an adaption from Henschel, Bargel and Cross (2021). However, in this study an altered Social-Technological Network task by Hortensius (in preparation) was implemented. The category 'you' was added to measure how people rate their own mind perception in terms of agency and experience. In the task itself mind perception was measured through ratings of seven categories: animate (humans and animals) and inanimate agents (robots, virtual assistants) and technological objects (tools, appliances, media, transport). Per category participants had to rate six images on the dimensions of agency: the ability to plan and act (the scale ranges from no agency to full agency) and experience: the ability to sense and feel (the scale ranges from no experience to full experience). These definitions are derived from Henschel, Bargel and Cross (2021). The procedure of the Social-Technological Network task is visualized in figure 1.

Figure 1

Social Technological Network Task

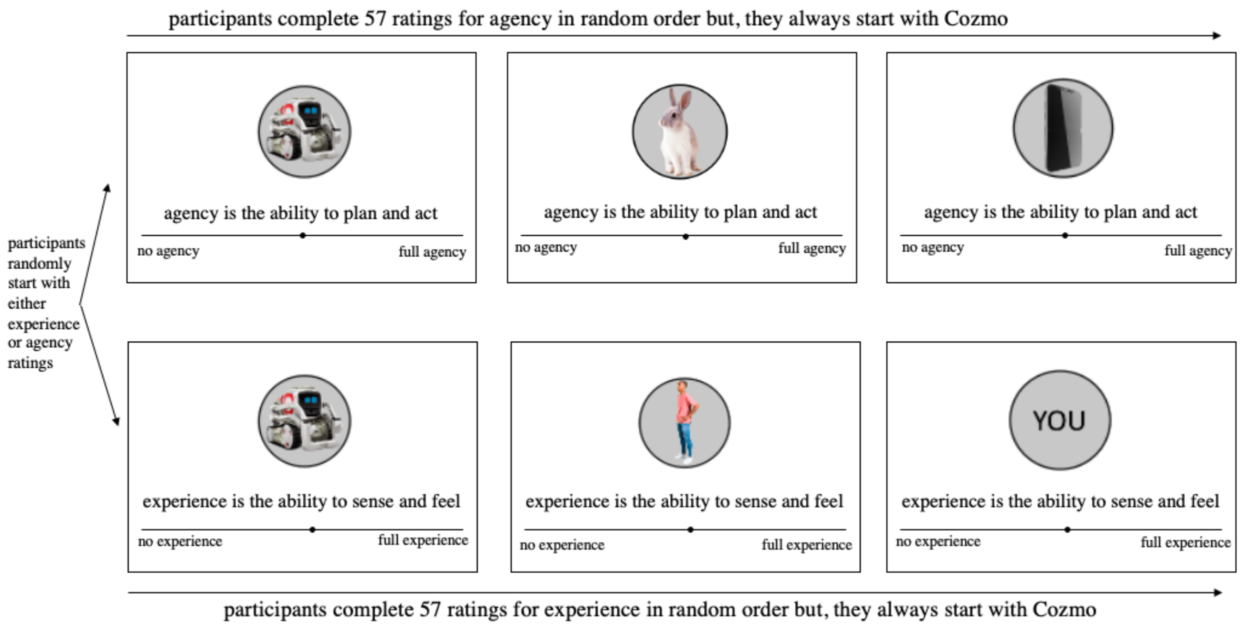


Fig.1: Visualization of the procedure for the social-technological network task with the inclusion of you (self).

2.5. Diffusion of responsibility task

The Diffusion of Responsibility task aims to measure the behavioural consequences of a change in perceived agency and experience. This task is based on a model explaining Sense of Agency in human-human interaction by Beyer and colleagues (2017). Ciardo and colleagues (2020) adapted this task to study the influence of the attribution of intentional agency to a robot, on people's Sense of Agency. Thus, adjusting this human-human interactive model to fit a human-robot interactive play (Ciardo et al., 2020). In order to measure the effect of human-robot interaction on sense of agency, they used a Diffusion of Responsibility task. Participants were asked to work together with Cozmo the robot in certain trials and worked alone on others. The goal of the Diffusion of Responsibility task is to stop a balloon, which is shown on a screen, from bursting. This goal is reached if the balloon is stopped from reaching a pin (Ciardo et al., 2020).

In this study an adapted version of the previously mentioned Diffusion of Responsibility task was used, consisting of 20 trials. Each trial consists of several stages (figure 2). At the start of the task, a screen with instructions will appear, afterwards the practice trial will start. Next, the balloon will be shown at its starting size for 1000ms, then the inflation of the balloon will start. Across trials the speed at which the balloon inflates varies and the point in the sequence at which the balloon pops will vary per trial as well. The participant can stop the inflation of the balloon at any time in the sequence by clicking the 'stop the balloon' button. Depending on the point in the sequence where the participant stops the balloon from bursting, a certain number of points will be lost. If the participant did not press the button during the trial, the balloon bursts and 'Oh no the balloon burst' will be shown on a screen for 2000ms. At the end of each trial the number of points lost will be shown on the screen for 5000ms. This amount varies between 0 and 20.

In the current study, the payoff structure used is based on the maximum size of the balloon and the point at which the participant presses the button (table 1). After each trial, participants receive two questions on the amount of control they felt and the amount of anxiety they felt on a visual analogue scale. The amount of anxiety participants felt is used to measure the sense of experience. In the Social Technological Network task, participants rate multiple pictures on agency and experience. In this Diffusion of Responsibility task, both agency and experience will be measured on a behavioural level by asking participants to rate the amount of control and anxiety they felt during the trials.

The control scale to measure the sense of agency spans from "No control" on the one side to "Full control" on the other. The anxiety scale to measure sense of experience from "No anxiety" on the one side to "Full anxiety" on the other. After the anxiety question, the next trial will start by displaying the balloon's starting size once more. Before the main trial begins the participants can practice once (and can also choose to practice again). After the practice trial, a screen displaying 'main task starting' is shown for 4000ms.

Figure 2
Adjusted Diffusion of Responsibility task

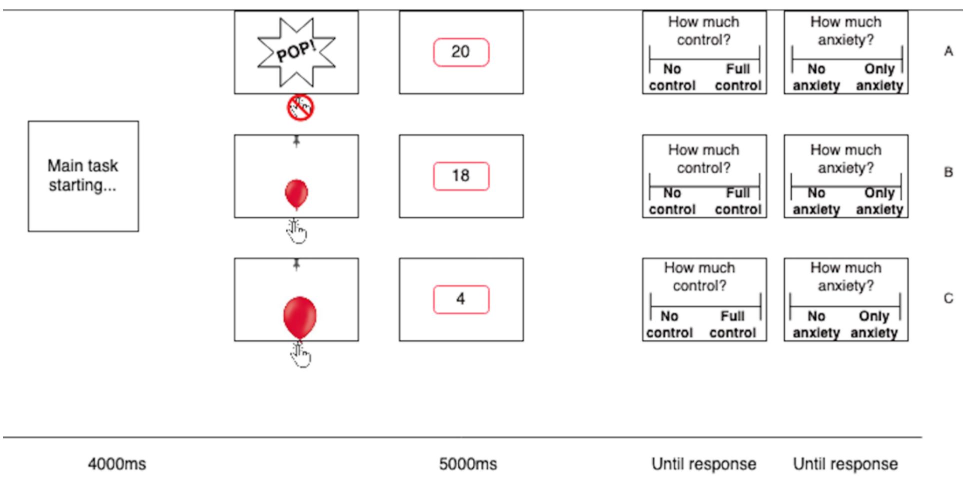


Fig 2. Diagram of adjusted task procedure with A: missed trial; B: low risk-taking trial; C: high-risk taking trial.

Table 1

Pay-off Structure of the adjusted Diffusion of Responsibility task

Screens passed	Maximum screens	Lost points
0	2-20	20
5	5-20	0-15
10	10-20	0-10
15	15-20	0-5
20	20	0
not pressed	2-20	20

*Formula: 20 - ((20 / Maximum Screens) * Screens Passed)*
*Example: 20 - ((20 / 16) * 10) = 10*

Table 1: The pay-off structure that is used to calculate the amount of points a participant gets during the Diffusion of Responsibility task.

2.6. Knowledge manipulation

After completing the first Social-Technological Network task and the first Diffusion of Responsibility task, participants watched a video that provided further information on the basic functionality (e.g., movement and face recognition) of the Cozmo robot. The video either showed the basic functionality from a mechanical point-of-view or from an intentional point-of-view. The visual components of the video were identical for each manipulation: Cozmo was visible on a white tabletop with a green backdrop and was moving around during the video. The video clip started with the text: *"This is the Cozmo robot. In this short videoclip we will describe the functionality of this robot"*. Then the video would either continue from the mechanical or intentional point-of-view. For the mechanical video clip, the text continued with: *"Cozmo is a small robot and has 50 gears and 4 motors that dictate it to navigate and move its arms and head. The robot is rigid with a fixed behavioural repertoire. Its behaviours are scripted and stable over time. These behaviours are based on programmed scripts.*" In contrast, for the intentional video clip, the text continued with: *"Cozmo is a small robot and has 50 gears and 4 motors that allow it to navigate and move its arms and head. The robot is flexible with an expanding behavioural repertoire. Its behaviours are learned and evolve over time. These behaviours are based on artificial intelligence."* The only difference between the two videos was the manipulation related text as mentioned above.

Participants were randomly assigned into two groups. One group watched the intentional (N = 40) and the other the mechanical (N = 36) video manipulation. Previous research by Hortensius (in preparation) has shown that the intentional description will increase both the ratings for agency and experience of a robot and that the mechanical description will decrease both the ratings for agency and experience of a robot (i.e., a difference of +6.8 for agency and +16.1 for experience, and -4.8 for agency and -4.3 for experience respectively). This double dissociation in the Social-Technological Network rating task is expected in this study as well.

2.7. Experimental Procedure

The experiment started with informed consent and thanking the participants for participating in this study. They were informed about the duration of the study as well as a general overview about the procedure. Then participants had to perform the Social-Technological Network task for the first time to establish a baseline rating for agency and experience. After this, the participants completed the first Diffusion of Responsibility task to establish a baseline rating for sense of control and sense of anxiety. Afterwards, the knowledge manipulation was shown, either with video of Cozmo from a mechanical point-of-view or an intentional point-of-view. Besides the knowledge manipulation everything in this experiment was the same for all participants.

After the knowledge manipulation participants did both the Social-Technological Network task and the Diffusion of Responsibility task again in order to measure the hypothesized effect of the knowledge manipulation. After the experiment the participants provided information on their exposure to different types of technology such as, virtual assistants, smartphones, smart watches, robots, and internet of things. Then participants were asked to state their preferred gender and age. Lastly, they were probed for their suspicion about the goal of the research, debriefed and thanked.

Figure 3
The Experimental Procedure

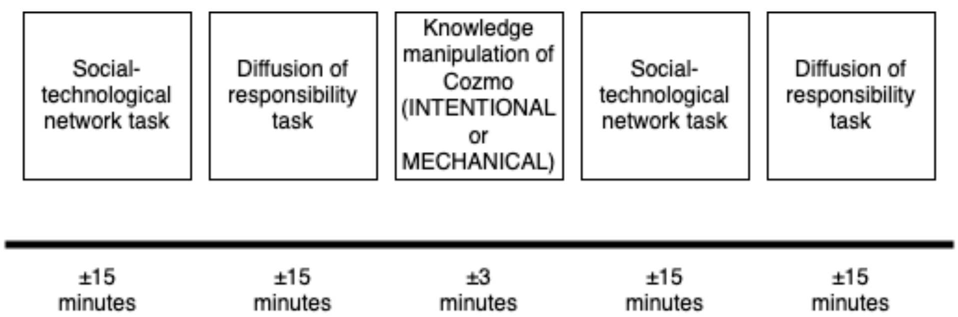


Figure 3. Visualization of the order and duration of the experimental procedure of the current study

3. Results

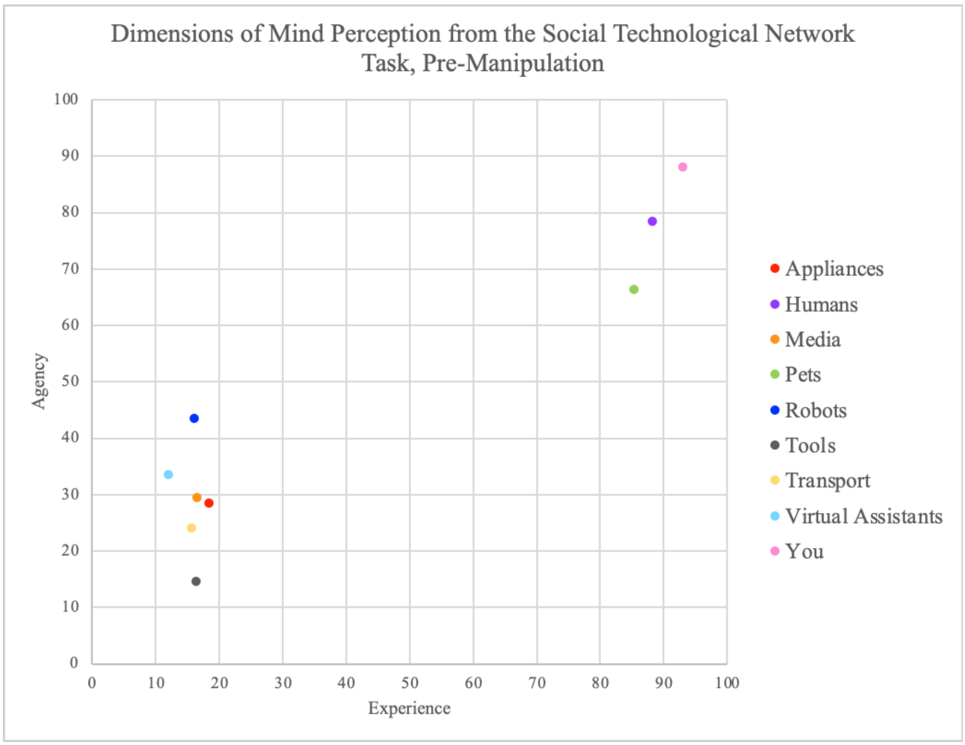
To analyse the data, the ratings from the second Social-Technological Network task (POST) were subtracted from the ratings of the first Social-Technological Network task (PRE). This way the effect of the manipulation could be studied more efficiently. This applies to all the data in this experiment unless stated otherwise.

3.1. Social Technological Network Task

The Social-Technological Network task is used to establish ratings of the dimensions of mind perception, agency, and experience. In figure 4 the average ratings of all participants before the manipulation are presented. As depicted below, the category 'you' is rated the highest on both agency and experience pre-manipulation. The categories 'humans' and 'pets' are rated a little less for both experience and agency, but still very high respectively. The category 'Virtual assistants' got the lowest experience rating and the category 'Tools' was rated the lowest on agency. 'Robots' were rated quite high on agency and very low on experience.

Figure 4

Dimensions of Mind Perception from the Social Technological Network Task before the manipulation



The mean of the *agency* ratings for *Cozmo* decreased after the mechanical manipulation and increased after the intentional manipulation (*M = -4.000, SD = 25.441* and *M = 7.350, SD = 28.456*, respectively).

This effect was expected and in line with earlier results found by Hortensius (in preparation). However, this effect was found to be non-significant *t (*74) = -1.825 and *p* = .072 (figure 5)

The mean of the *experience* ratings for *Cozmo* increased more for the intentional manipulation than for the mechanical manipulation (*M = 14.375, SD = 27.380* and *M = 3.806, SD = 24.999*, respectively). This effect was expected for the intentional manipulation, but the mechanical manipulation was expected to decrease instead of increase. Moreover, this effect was found to be non-significant with *t (*74) = -1.751 and *p* = .084 (figure 5).

The mean of the *agency* ratings for *self* increased more for the mechanical manipulation than for the intentional manipulation (*M = 4.917, SD = 11.589* and *M = 1.775, SD = 12.007*, respectively). This effect was found to be non-significant with *t (*75) = 1.158 and *p* = .251 (Figure 5).

The mean of the *experience* ratings for *self* decreased in both the mechanical and intentional condition after the manipulation (*M = 2.111, SD = 9.931* and *M = -1.225, SD = 16.124*, respectively). This effect was found to be non-significant with *t (*74) = -0.285 and *p* = .777 (figure 5).

Figure 5
Mean differences for agency and experience for both self and Cozmo

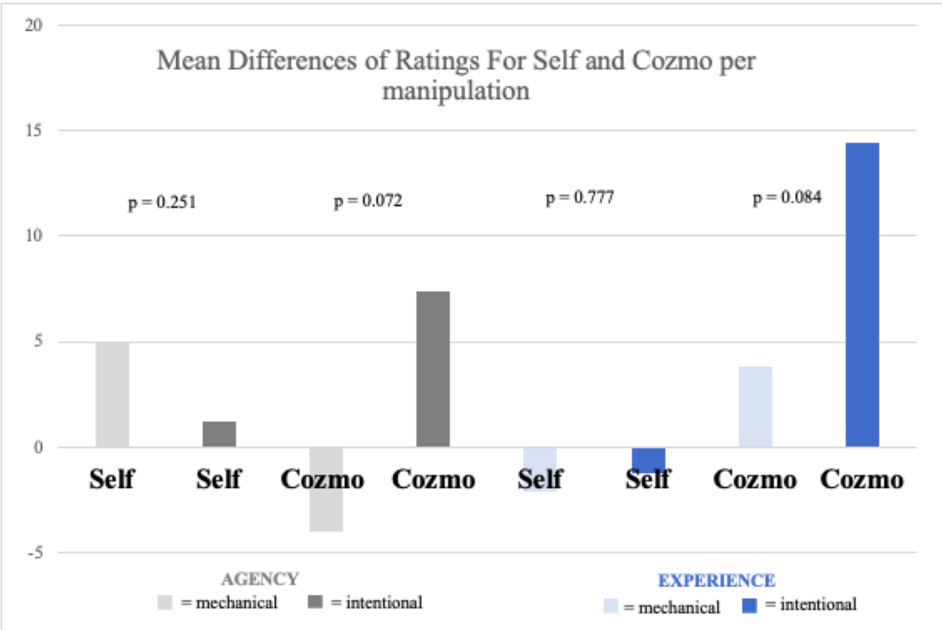


Figure 5: Visualization of the mean differences of ratings for self and Cozmo for the mechanical and intentional manipulation with the p-values of the independent t-tests

3.2. Diffusion of Responsibility task

Sense of Agency ratings increased more on average in after the manipulation in the mechanical group in contrast to the intentional group (M = 1.099, SD = 13.235 and M = 0.678, SD = 11.904, respectively). However, this effect was not significant with t (74) = 0.15, p = .884 (figure 6)

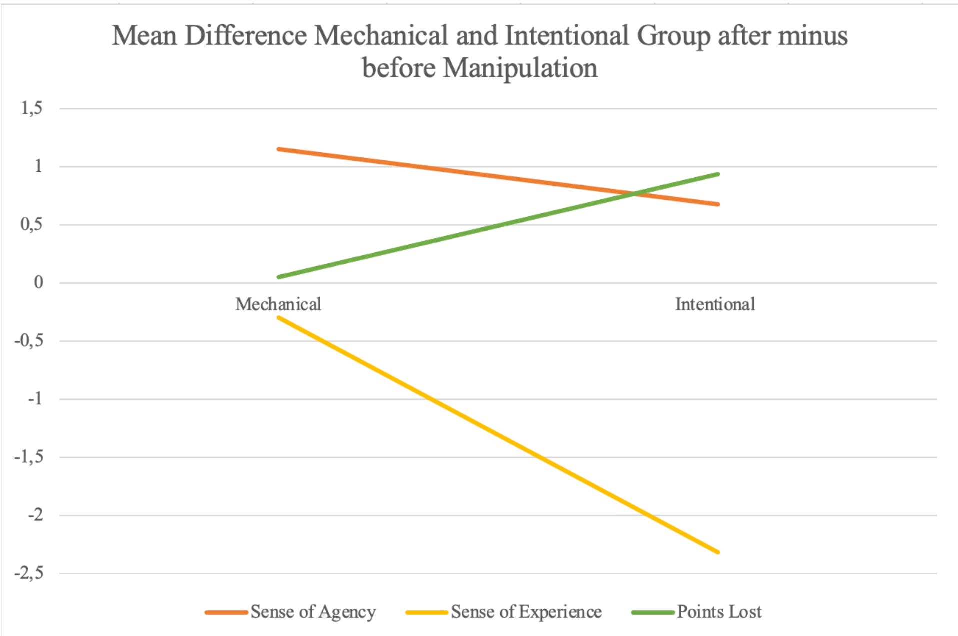
Sense of Experience ratings decreased more on average after the manipulation for the intentional group than in the mechanical group (M = -2.319, SD = 14.181 and M = -0.296, SD = 11.128 respectively). However, the effect was not significant with t (74) = 0.69, p = .495 (figure 6).

Independent of the manipulation, both sense of agency ratings and sense of experience ratings did not differ significantly from zero (t (39) = -1.03, p = .307 and t (35) = -0.16, p = .874 for intentional and mechanical sense of agency respectively; t (39) = 0.36, p = .721 and t (35) = 0.49, p = .622 for intentional and mechanical sense of experience respectively).

The outcome (number of points lost) increased on average in both groups (M = 0.053, SD = 2.596 and M = 0.936, SD = 3.063, for the mechanical and intentional groups respectively). However, the groups did not differ significantly from each other with t (74) = -1.35, p = .182 (figure 6). Correlating the sense of agency, sense of experience and the outcome with each other, the pre-scores negatively correlated with sense of agency (r (74) = -.29, p = .009) and positively correlated with sense of experience (r (74) = .22, p = .051).

Figure 6

Mean difference between the mechanical and intentional group and points lost



3.3. Exploratory Analysis

A repeated measures ANOVA was conducted to compare the manipulation with the categories of the Social Technological Network task. There was a statistically significant main effect of category when rating *experience* (F (8) = 4.360, $p < .001$), meaning that categories differ from each other, independently from the manipulation. A post hoc test revealed that the categories that differed from each other were all the categories except from self and virtual assistants when compared to the category robots. The experience rating of robots increased more on average after the manipulations than the ratings of appliances, humans, media, pets, tools, and transport. When rating *agency*, there was a significant main effect of category as well as an interaction effect between category and manipulation (F (8) = 11.540, $p < .001$ and F (8) = 4.026, $p < .001$ respectively). This interaction effect means that the two groups (intentional and mechanical groups) differed from each other within a category. A post hoc test revealed that the mechanical group (-8.014 ± 19.870 agency, $p = .014$) rated robots lower in agency than the intentional group (4.861 ± 15.526 agency), however no differences were detected between mechanical and intentional for any other category.

Table 2
Post Hoc Comparisons between manipulations

Post Hoc Comparison – Manipulation*Condition		**Mean difference**	**SE**	**t**	**p**
Mechanical, appliances	Intentional robots	-11.417	3.163	-3.609	.044
Intentional, humans	Mechanical, media	11.440	3.163	3.617	.043
Intentional humans	Mechanical, va	15.644	3.163	4.946	<.001
Intentional, self	Mechanical, va	13.185	3.163	4.169	<.001
Mechanical, media	Intentional, pets	-12.657	3.163	-4.002	.010
Mechanical, media	Intentional, robots	-13.565	3.163	-4.289	.003
Intentional, pets	Mechanical, robots	11.968	3.163	3.784	.023
Intentional, pets	Mechanical, va	16.861	3.163	5.331	<.001
Intentional, robots	Mechanical, robots	12.875	3.280	3.925	.014
Intentional, robots	Mechanical, transport	12.190	3.163	3.854	.018
Intentional, robots	Mechanical, va	17.768	3.163	5.816	<.001
Intentional, tools	Mechanical, va	13.417	3.163	4.242	.004

Table 2: Post Hoc Comparison with all significantly differing mean scores between the different manipulations

Figure 7

Post-manipulation changes in agency and experience

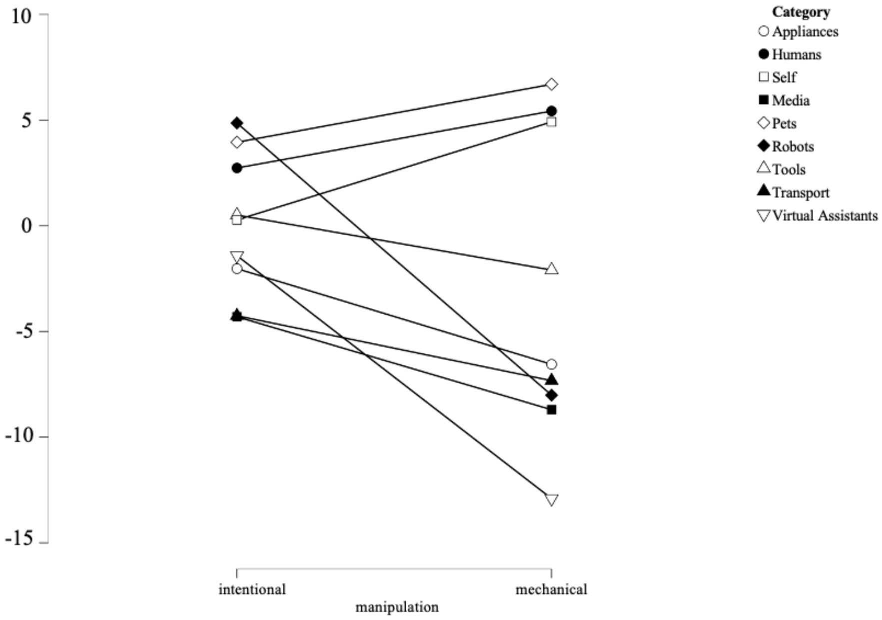


Figure 7: Visualization of the changes after the intentional and mechanical manipulation for agency for each condition

Moreover, it became apparent that a large group of participants was in their twenties and only a few (N = 9) were over thirty. However, a control analysis revealed that for the manipulation check there was no change in data other than for the rating of agency for Cozmo. Agency for Cozmo decreased after the mechanical manipulation (N = 32) and increased after the intentional manipulation (N = 35) (*M = -6.500, SD = 24.590* and *M = 8.534, SD = 24.080*, respectively). This effect was now found to be significant with t (65) = -2.528 and p = .014.

Besides the changes in ratings of Cozmo, analysis to establish the effect of the manipulation on the mean scores of all the robots were done. Overall, after the mechanical manipulation agency ratings decreased and after the intentional manipulation, they increased (*M = -8.014, SD = 19.870* and *M = 5.421, SD = 15.777*, respectively). This effect was found to be significant with t (74) = -3.280 and p = .002 (Figure 7). In contrast to the agency ratings, the experience ratings increased after both the mechanical and the intentional manipulation. The intentional manipulation yielded the largest increase (*M = 5.149, SD = 21.553* and *M = 9.350, SD = 21.189*, respectively). However, this effect was found to be non-significant with t (74) = -0.847 and p = .400.

Figure 8

Mean Difference for agency ratings of all robots

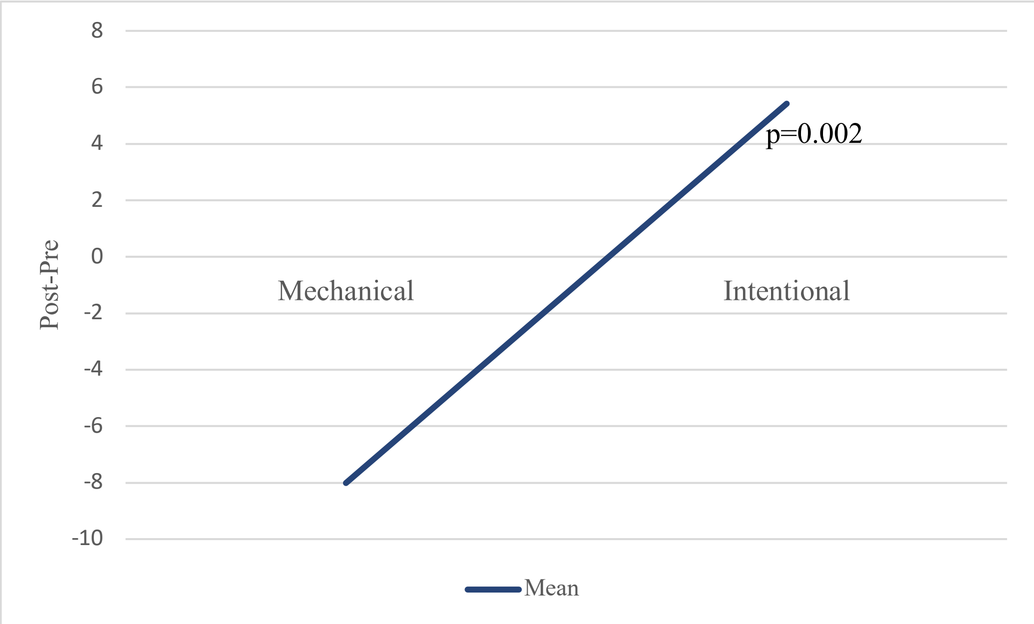


Figure 8: Changes in mean difference between mechanical group and intentional group of all robots for agency including p-value from the independent t-test.

Further analysis was done on the *agency* ratings of the different other humans. For children the ratings increased after both the mechanical and intentional manipulation (*M = 24.250, SD = 34.406* and *M = 25.625, SD = 30.786*, respectively) with *t (*74) = 0.184 and *p* = .855. For regular adults the ratings increased after the mechanical manipulation and increased slightly for the intentional manipulation (*M = 13.986, SD = 28.822* and *M = 1.988, SD = 23.911,* respectively) with *t (*74) = 1.982 and *p* = .051. Lastly, for elderly people the opposite effect was found namely after the intentional manipulation agency increased and after the intentional manipulation agency decreased (*M = 9.063, SD = 27.043* and *M = -10.264, SD = 30.956*) with *t (*74) = -2.905 and *p* = .005 (figure 9).

Figure 9

Changes in Agency rating per age category for each manipulation

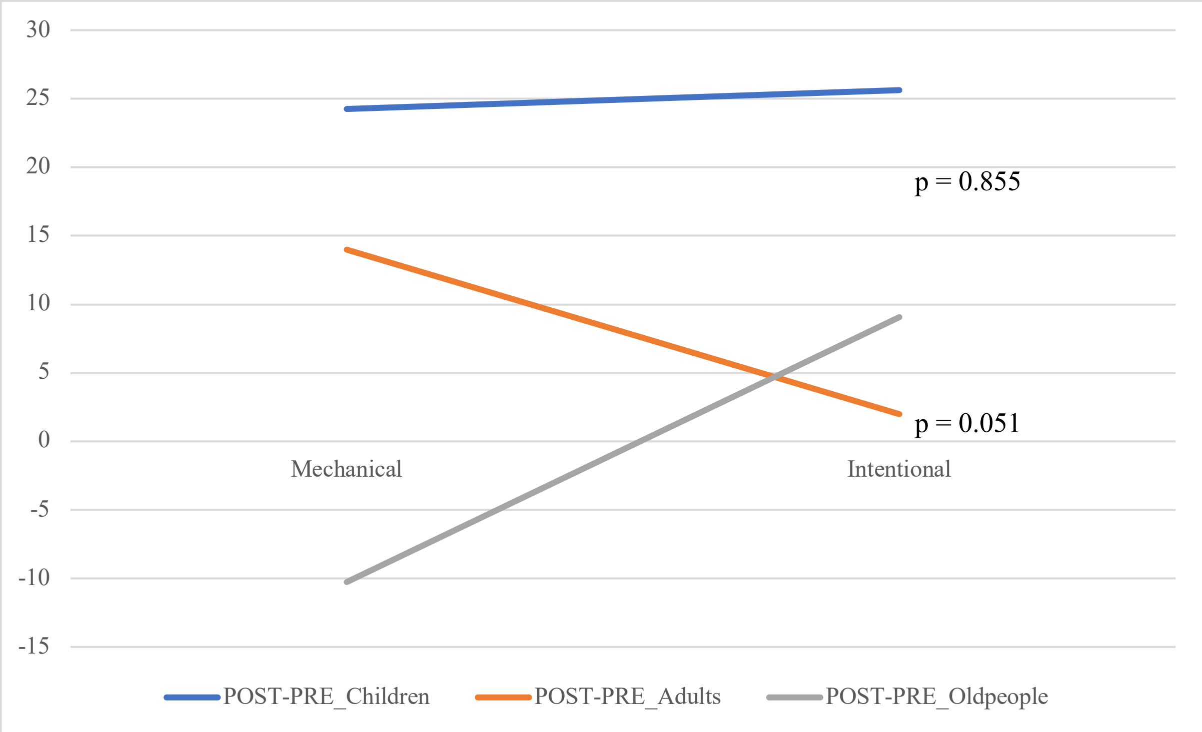


Figure 9: Changes in agency rating per age category for the mechanical group and the intentional group including the p-values from the independent t-tests.

This variance in agency ratings suggests that age plays a role in the ratings of agency and therefore might explain variance seen in the ratings of you. Therefore, it was decided that the two age groups should be correlated with their scores on agency of themselves. One group consisted of the data of the young adults (*N = 66, M = 22.652, SD = 2.337*) with the age range of 18 to 30. The other group consisted of the data of grown adults (*N = 9, M = 59.333, SD = 3.279*), consisting of the data from all participants over 30. However, the minimum age within this group was 54 and the maximum age was 65. Therefore, the data of the grown adults is not very useful because of its small range and small sample size. From this sample of young adults, it can be seen that there is one extreme outlier with the age of 20 scoring 0 on agency. Therefore, this participant was deleted from the correlation. The new correlation however, showed that there is no linear relationship between age and rating of agency for self with r = 0.057 and p = .650 in the group with young adults.

Lastly, since the results of the Diffusion of Responsibility task were non-significant for both the manipulation and independent of the manipulation, we correlated sense of agency measured as control from the first Diffusion of Responsibility task with the first agency ratings from the Social Technological Network task in a one-tailed positively correlated regression test and found r = 0.070

with p = .273. This suggests that sense of control was not a good proxy for sense of agency in this experiment.

4. Discussion

4.1. General discussion

The research question that this study aimed to answer with this exploratory study was: "Can changes in robot mind perception change people's own mind perception and control of behaviour?".

For the Social Technological Network task changes in robot mind perception did not significantly influence mind perception of self. However, ratings of agency for robots in general (Cozmo, Darwin, Kuri, Nao, Pepper and Zenbo) significantly decreased after the mechanical manipulation and a significant increased after the intentional manipulation. This effect suggests that the manipulation worked, but it simply did not have an effect on the agency and experience ratings of the self. When analysing the data from all the participants the result for Cozmo the robot was the only result that had a non-significant effect of manipulation on the agency rating. Nonetheless, after deleting all participants over 30 years old the agency rating for Cozmo did significantly change after the knowledge manipulation. This result suggests that the older people in the study might have a more conservative view towards robots and therefore this might have influenced their stance on the experiment and their attitude towards the manipulation.

Moreover, agency for other humans (than self) changed after the knowledge manipulation. Agency of adults decreased in the intentional condition and increased in the mechanical condition. The opposite was true for agency of elderly people: decrease in the mechanical condition and an increase in the intentional condition. This finding suggested that there might be an effect of age on ratings of agency and this effect might also have an influence on the ratings of self. After a correlation analysis, no effect was found. Yet, since this study was an exploratory study, a convenience sample was used and therefore this study did not have the biggest age range. A follow-up study with a more diverse range might yield a correlation between age and rating of self.

The ratings of experience in the Social Technological Network task showed no significant effect. Not for ratings of Cozmo, not for ratings of self, not for ratings of other people and not for ratings of other robots. This suggests that the rating of experience is more complex than previously expected. In a study by Gray et al. (2011) it was suggested that experience ratings are strongly linked to the perception of biological bodies. The most obvious reason they present for this suggestion is that most of our perceived experiences are mediated by our physical organs such as the skin, eyes, and noses (Gray, et al., 2011). People are more willingly to ascribe "knowledge" or "beliefs" to robots, but without the flesh people are more reductant to ascribe them with emotional capacities such as pain or hunger (Huebner, 2010).

The Diffusion of Responsibility task that was implemented, was an altered task from Ciardo et al. (2020) in which participants originally played with a robot. In the current study participants had to do the task twice, with the idea in mind that the results would differ pre-and post-manipulation. The task was not previously executed in this manner before. The previous study showed that sense of control correlated negatively with the points participants lost in each trial. That effect was found in this study as well. The current study consisted of an additional question on anxiety, aiming to measure experience. Anxiety positively correlated with points lost, as expected. No significant effect was found from the knowledge manipulation on sense of agency nor on sense of experience. Yet, the effect that was found, was in the expected direction. Namely that participants in the intentional group experienced less anxiety on average after the manipulation than the mechanical group. For sense of control the mechanical group felt more control on average after the manipulation than the intentional group. Nonetheless, the differences in these measurements did not significantly differ from zero, meaning that it might not be fruitful to perform the Diffusion of Responsibility task twice. Besides, sense of agency measured in feelings of control did not correlate significantly with agency measured in the Social Technological Network task, suggesting that sense of agency was not measured with the control question. Moreover, in the original Diffusion of Responsibility task of Ciardo et al (2020) the Diffusion of Responsibility task is performed with Cozmo or with an air pump. The Diffusion of Responsibility task in the current study lacked this both physical and social component due to the experiment being online instead of in the lab. In the study of Lefkeli and colleagues (2020) it was suggested that perceiving Cozmo, the speeds of its movements and its social cues particularly trigger mind perception. Furthermore, the general interaction between human and robot influences the interpretation and potential triggers of mind perception. Thus, the physical lack of Cozmo during the Diffusion of Responsibility task probably influenced the results strongly. Future studies should focus on replicating this study in a lab, implementing the Diffusion of Responsibility task, and having Cozmo physically present.

In the study by Ciardo et al. (2020) it was already suggested that embodiment plays a crucial role when studying sense of agency and it was to be expected that this would be the same for sense of experience. The robots in this study were not embodied due to the experiment being online. And this might have significantly influenced the results for both the Social Technological Network task and the Diffusion of Responsibility task. A meta-analysis by Li (2015) aimed to examine if people responded differently to physical and virtual agents. In 73% of the selected studies (N = 33) a physical robot performed better, was rated to be more persuasive, received more attention and overall was perceived more positively than a virtual agent. This effect was also found when the behaviour of the robot was identical to the behaviour of the virtual agent and when both agents had similar appearance. Li (2015) focused its study on if the robot was virtually co present (acting and responding on the screen) or tele present (shown on the screen). Tele-present robots were less favourable again. The effect of embodiment of robots is measured in many other studies as well. Brainbridge et al. (2011) found that participants were more likely both to fulfil an unusual request and to afford greater personal space to the robot when it was physically present, rather than when it was shown on live video. And that they reported an overall more positive interaction with the physically present robot. Wang & Rau (2019) found that tele-present robots were least favoured (over physical, virtual, and animated robots) and this influenced both attitude and faith negatively. Yet another study found that when cooperating in a task with a robot, participants found an embodied robot to be more appealing and perceptive of the world than non-embodied robots. It was also demonstrated that compared to a remote tele-present robot and a simulated robot, the embodied robot was seen as most helpful, watchful, and enjoyable (Wainer, et al. 2007). All together these studies suggest that there is a clear effect of embodiment on attitudes and beliefs of the participants towards tele-present robots. This might have affected the results of the current study as well.

Besides, the perception of robot also depends on the appearance of the robot. In this study different types of robots were used: Cozmo, Darwin, Kuri, Nao, Pepper and Zenbo. These robots all have different appearances, which can influence judgement, just like the judgment of humans can be influenced by physical appearance. According to earlier research the social perception of people is based on two components: warmth and competence (Fiske, Cuddy, & Glick, 2007). Warmth and competence are the main drivers in the formation of judgements about other humas. Usually, the warmth judgments come before the competence judgement and warmth judgments are more important. Overall, people when evaluated as warm and competent are seen as more favourable and these people have more positive interactions with others (Carpinella, et al., 2017). And it has been found that warmth judgments are very important for the judgement of robots as well (Ho, & MacDorman, 2010). Besides warmth, based on the appearance of robots, people make social judgements about other aspects of robots too, for example gender, race, and nationality. An interesting study by Eyssel and Hegel (2012) revealed that a short-haired male robot is perceived as more agentic than a female robot with long hair. On the contrary, the female robot was perceived as more communal. Analogously, stereotypically male tasks were perceived more suitable for the male robot, relative to the female robot, and vice versa. This stereotyping might even have an influence on how people anthropomorphize robots. People are more likely to anthropomorphize robots when human characteristics are accessible and applicable, for example when they have recently been used or when robots appear more humanlike (Epley, Waytz, & Cacioppo, 2007). The study by Ferrari, Paladino and Jetten (2016), in which the level of mind attribution was affected by the level of anthropomorphism sheds an interesting light on this idea. If robots who look more like humans get ascribed more of a mind, and in turn pose a bigger threat to human uniqueness, this could perhaps influence the perception of the self. And it is also seeming to be the case that an 'in-group' robot is more likely to be anthropomorphized, which suggests that the qualities of a robot are malleable based on the characteristics of the perceiver of the robot (Kuchenbrandt, et al., 2013). This mechanism might explain the fact that the psychical appearance of Cozmo, which is not human-like might have influenced the judgements of warmth and competence, but also agency and experience. Since another remarkable finding in this study was, that Cozmo was the only robot that was not rated significantly higher in agency after the knowledge manipulation in first instance. Having said that, after the exclusion of the older participants from the study a significant effect was found.

Furthermore, Cozmo is known to be a social robot designed for children with more than 900 pre-programmed behaviours (McNeill, & Kennington, 2019). However, based on the previous section the question arises if Cozmo was the right target robot. For example, in the exploratory study of Barco et al. (2020) children applied more anthropomorphism toward NAO than towards Cozmo. In the current study the effect of the manipulation was also higher for NAO and, more importantly, significant. The agency rating of Cozmo was slightly higher (difference in mean agency was 0.125) but the knowledge manipulation was focused on Cozmo, so that is an interesting finding. The NAO robot is in looks more similar to humans than the Cozmo robot. The NAO robot has two arms and legs and a head with facial expressions. This human like appearance could have an influence over applied anthropomorphism as seen in the previous study. However, another study focused on mind perception, agency, and experience towards NAO. The study of van der Woerdt and Haselager (2019) used videos of NAO failing because of lack of effort and found that participants actually rate these robots as higher in agency, but not experience. But this unpredictability of the robot might increase the feeling of anthropomorphism, not robot NAO itself. The studies that used NAO did not include agency or experience measures like the studies of Cozmo. NAO is used in studies measuring more high-level social behaviours like cheating in a game (Haring et al., 2019). Therefore, a suggestion for future could be doing a study like the current study but using a different more human-like robot as NAO as a target robot for the manipulation. This has not been done before but, might create bigger effects for both agency and experience for the robot as for changes in ratings of self.

In the original paper of Gray, Gray and Wagner (2007) the respondent self was rated high on experience and agency. In the current study this effect was not found at all. Ratings of self on experience became even lower in both conditions after the knowledge manipulation and agency ratings of self were lower than expected. The feeling of sense of agency or sense of experience and the rating of one's own agency or experience might not be as easy to measure as initially expected. Agency is closely related to self-awareness. The sensorimotor basis of self distinguishes two aspects of self- awareness: (1) the recognition of authorship of our own voluntary action and of their consequences (2) and the recognition of our body as our own on the basis of our individual experience of the world. The human brain generates a sense of agency even with highly complex, devolved, and indirect causal chains. For example, when pushing the button of an automatic juice press to make fresh orange juice can invoke feelings of agency. Yet, the overall feeling of agency depends on a much wider range of events, including the fact that the oranges get into the machine, have been cut and been pressed into fresh orange juice that ends up into a bottle and tastes delicious (or not). Thus, even when an action involves a sequence of several steps involving intermediate events, technologies, or even actions carried out by other agents, we may still feel some feelings of agency over the causal chain as a whole (Caspar, et al., 2015). This sense of agency feeling is hard to measure in any other way then to directly ask a participant in the form of self-report. And in case of the Social Technological Network task, the question might not have been so clear as in the instance of "Did you just make orange juice?". So, besides that agency over one's actions is a complex phenomenon, it is also very hard to measure. For the Diffusion of Responsibility task, the sense of agency task made more sense. Yet, in situations in which the balloon popped the participants could have experienced lower sense of agency due to the fact that the balloon popped and not due to the manipulation of the intentional or mechanical view of Cozmo. And the same is true for the sense of experience which was measured as anxiety. Moreover, some participants provided feedback, stating that the balloon popped too soon and that this felt unfair. For some this even caused feelings of anger but not always changes in sense of control. This means that the Diffusion of Responsibility task might trigger different responses than just the ones that were measured. Nonetheless, there might be an alternative explanation for differences in ratings of self for agency and experience. The theory of human uniqueness by Bingham (1999) states that the diverse features of humans present are referred to as the 'human uniqueness problem'. This is thought because humans possess adaptive capabilities for among other things language, high cognitive function, and technological virtuosity, different than from any other creature on this planet.

4.2. Practical limitations

There are a few limitations to this study that are directly related to the design. The limitations in question are quite common in psychological research, however they should be briefly discussed. Firstly, the experiment was conducted online due to the COVID-19 pandemic. Therefore, participants were completing the experiment online at home and thus the participants might have been less motivated or less concentrated than in the real experimental setting. This might have led to different or less well thought out answers. Secondly, the length of the experiment was quite extensive and since the experiment was online (causing a lack of social interaction) this might have significantly affected the results for the second ratings. Especially the Diffusion of Responsibility, since this was quite an extensive task that had to be completed at the very end of the experiment. Thirdly, the diversity of age in the group was limited with almost all participants in their twenties which might have led to a certain bias (due to the convenience sample). Lastly, the group size was 76 participants who might not be sufficient for an in-between subject's study-design. Nonetheless, since this was an exploratory study any effect that was found is useful.

4.3. Conclusion

This exploratory study aimed to answer the question if a change in the mind perception of a robot could change people's own mind perception and if this change would be related to behaviour. The results suggest that the manipulation did not change people's own mind perception. A change in behaviour was not found either. The effects did all move in the right direction of what was expected, meaning that the significance might be found with an altered research design with suggestions from above.

5. References

Barco, A., de Jong, C., Peter, J., Kühne, R., & van Straten, C. L. (2020, March). Robot Morphology and Children's Perception of Social Robots: An Exploratory Study. In *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 125-127).

Beyer, F., Sidarus, N., Fleming, S., & Haggard, P. (2018). Losing control in social situations: how the presence of others affects neural processes related to sense of agency. *eneuro*, *5*(1).

Beyer, F., Sidarus, N., Bonicalzi, S., Haggard, P. (2017). Beyond self-serving bias: diffusion of responsibility reduces sense of agency and outcome monitoring. *Social Cognitive and Affective Neuroscience, 12*(1).

Bingham, P. M. (1999). Human uniqueness: a general theory. *The Quarterly Review of Biology*, *74*(2), 133-169.

Bossi, F., Willemse, C., Cavazza, J., Marchesi, S., Murino, V., & Wykowska, A. (2020). The human brain reveals resting state activity patterns that are predictive of biases in attitudes toward robots. *Science robotics*, *5*(46).

Caspar, E. A., Cleeremans, A., & Haggard, P. (2015). The relationship between human agency and embodiment. *Consciousness and cognition*, *33*, 226-236.

Carpinella, C. M., Wyman, A. B., Perez, M. A., & Stroessner, S. J. (2017, March). The robotic social attributes scale (rosas) development and validation. In *Proceedings of the 2017 ACM/IEEE International Conference on human-robot interaction* (pp. 254-262).

Ciardo, F., Beyer, F., De Tommaso, D., & Wykowska, A. (2020). Attribution of intentional agency towards robots reduces one's own sense of agency. *Cognition*, *194*, 104109.

Epley, N., Waytz, A., & Cacioppo, J. T. (2007). On seeing human: a three-factor theory of anthropomorphism. *Psychological review*, *114*(4), 864.

Eyssel, F., & Hegel, F. (2012). (s) he's got the look: Gender stereotyping of robots 1. *Journal of Applied Social Psychology*, *42*(9), 2213-2230.

Ferrari, F., Paladino, M. P., & Jetten, J. (2016). Blurring Human–Machine Distinctions: Anthropomorphic Appearance in Social Robots as a Threat to Human Distinctiveness. *International Journal of Social Robotics*, *8*(2), 287–302. https://doi.org/10.1007/s12369-016-0338-y

Fiske, S. T., Cuddy, A. J., & Glick, P. (2007). Universal dimensions of social cognition: Warmth and competence. *Trends in cognitive sciences*, *11*(2), 77-83.

Graupmann, V. (2018). Show me what threatens you, and I can tell who you are: Perception of threat and the self. *Self and Identity*, *17*(4), 407–417. https://doi.org/10.1080/15298868.2017.1412346

Gray, H. M., Gray, K., & Wegner, D. M. (2007). Dimensions of mind perception. *Science*, *315*(5812), 619-619.

Gray, K., Knobe, J., Sheskin, M., Bloom, P., & Barrett, L. F. (2011). More than a body: mind perception and the nature of objectification. *Journal of personality and social psychology*, *101*(6), 1207.

Gray, K., & Wegner, D. M. (2012). Feeling robots and human zombies: Mind perception and the uncanny valley. *Cognition, 125*(1), 125-130.

Haring, K., Nye, K., Darby, R., Phillips, E., de Visser, E., & Tossell, C. (2019, November). I'm not playing anymore! a study comparing perceptions of robot and human cheating behaviour. In *International Conference on Social Robotics* (pp. 410-419). Springer, Cham.

Henschel, A., Bargel, H., & Cross, E. S. (2021). Faces do not attract more attention than non-social distractors in the Stroop task. *Collabra: Psychology*, *7*(1).

Ho, C. C., & MacDorman, K. F. (2010). Revisiting the uncanny valley theory: Developing and validating an alternative to the Godspeed indices. *Computers in Human Behavior*, *26*(6), 1508-1518.

Huebner, B. (2010). Common-sense concepts of phenomenal consciousness: Does anyone care about functional zombies? *Phenomenology and the cognitive sciences*, *9*(1), 133-155.

Kuchenbrandt, D., Eyssel, F., Bobinger, S., & Neufeld, M. (2013). When a robot's group membership matters. *International Journal of Social Robotics*, *5*(3), 409-417.

Lefkeli, D., Ozbay, Y., Gürhan-Canli, Z., & Eskenazi, T. (2020). Competing with or Against Cozmo, the Robot: Influence of Interaction Context and Outcome on Mind Perception. *International Journal of Social Robotics*, 1-10.

Li, J. (2015). The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents. *International Journal of Human-Computer Studies*, *77*, 23-37.

McNeill, D., & Kennington, C. (2019). Predicting Human Interpretations of Affect and Valence in a Social Robot. In *Robotics: Science and Systems*.

Stafford, R. Q., MacDonald, B. A., Jayawardena, C., Wegner, D. M., & Broadbent, E. (2014). Does the robot have a mind? Mind perception and attitudes towards robots predict use of an eldercare robot. *International journal of social robotics*, *6*(1), 17-32.

Spunt, R. P., Meyer, M. L., & Lieberman, M. D. (2015). The default mode of human brain function primes the intentional stance. *Journal of cognitive neuroscience*, *27*(6), 1116-1124.

van der Woerdt, S., & Haselager, P. (2019). When robots appear to have a mind: The human perception of machine agency and responsibility. *New Ideas in Psychology*, *54*, 93-100.

Wainer, J., Feil-Seifer, D. J., Shell, D. A., & Mataric, M. J. (2007, August). Embodiment and human-robot interaction: A task-based perspective. In *RO-MAN 2007-The 16th IEEE International Symposium on Robot and Human Interactive Communication*(pp. 872-877). IEEE.

Wang, X., & Krumhuber, E. G. (2018). Mind perception of robots varies with their economic versus social function. *Frontiers in Psychology*, *9*, 1230–1230. https://doi-org.proxy.library.uu.nl/10.3389/fpsyg.2018.01230

Wang, B., & Rau, P. L. P. (2019). Influence of embodiment and substrate of social robots on users' decision-making and attitude. *International Journal of Social Robotics*, *11*(3), 411-421.

Wiese, E., Metta, G., & Wykowska, A. (2017). Robots as intentional agents: using neuroscientific methods to make robots appear more social. *Frontiers in Psychology*, *8*. https://doi-org.proxy.library.uu.nl/10.3389/fpsyg.2017.01663

Wiese, E., Wykowska, A., Zwickel, J., & Müller, H. J. (2012). I see what you mean: how attentional selection is shaped by ascribing intentions to others. *PloS one*, *7*(9), e45391.

Zwickel, J. (2009). Agency attribution and visuospatial perspective taking. *Psychonomic Bulletin & Review*, *16*(6), 1089-1093.