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Knock on Wood

Does Material Choice Change the Social Perception of Robots?

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ABSTRACT

This paper aims to understand whether there is a difference in how socially interactive robots are perceived based on the material they are constructed out of. Two studies to that end were performed; a pilot in a live setting and a main one online. Participants were asked to rate three versions of the same robot design, one built out of wood, one out of plastic, and one covered in fur. This was then used in two studies to ascertain the participants perception of competence, warmth, and discomfort and the differences between the three materials. Statistically significant differences were found between the materials regarding the perception of warmth and discomfort.

Ta i trä: Påverkar val av material den sociala uppfattningen av robotar?

SAMMANFATTNING

Denna uppsats undersöker huruvida det finns en skillnad i hur socialt interaktiva robotar uppfattas baserat på vilket material de är tillverkade i. Två studier gjordes för att ta reda på detta: En pilotstudie som skedde fysiskt, och huvudstudien skedde online. Deltagarna ombads att skatta tre versioner av samma robotdesign, där en var byggd i trä, en i plast och en täckt i päls. Dessa användes sedan i två studier för att bedöma deltagarnas uppfattning av robotarnas kompetens, värme och obehag, samt skillnaderna i dessa mellan de tre materialen. Statistiskt signifikanta skillnader hittades i uppfattningen av värme och obehag.

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ABSTRACT
This paper aims to understand whether there is a difference in how socially interactive robots are perceived based on the material they are constructed out of. Two studies to that end were performed; a pilot in a live setting and a main one online. Participants were asked to rate three versions of the same robot design, one built out of wood, one out of plastic, and one covered in fur. This was then used to ascertain their perception of competence, warmth, and discomfort and the differences between the three materials. Statistically significant differences were found between the materials regarding the perception of warmth and discomfort.

INTRODUCTION
In science fiction, robots are usually depicted as very human-like, or as metallic machine-like creatures. Commercial robots today are not at a stage of looking like humans and while humanoid robots exist, there are also robots made of plastic or organic materials such as wood or fabric. Depending on their target user group or application they can look like anything from almost human (Aaltonen et al. 2017) to a stuffed animal (Suguitan & Hoffman 2018). From non-embodied virtual assistants, such as Amazons Alexa or Apple's Siri, to robots that vacuum our floors or cut our grass, these devices are taking a physical place in our homes and our lives. Therefore, it becomes increasingly necessary to consider how to achieve the best possible communication between man and machine.

Communication is more than an exchange of information. It is also a social game of sorts, with give and take, where people tend to react badly if their expectations are not fulfilled adequately. In a conversation with another person there is a tendency to not only focus on what is being said, the exchange of information, but also things like the tone of voice, body language, and facial expressions. In fact, studies have shown that it can take as little as 100 milliseconds for a first impression to happen (Todorov 2013). For this reason, the physical appearance and in turn material of the robot becomes an important factor. If we, through choosing the correct material for our purpose, can shape impressions of robots from the first milliseconds of interaction we can work to overcome some of the areas where human-robot interaction tends to fall flat. Studies have shown that humans can react negatively when something feels off in interactions with robots (Mori et al. 2012). This has been the basis for much of the advances in the field of social robotics, to overcome these misgivings people may have towards interacting with robots in their everyday lives.

What separates robot design from many other forms of design is the aspect of embodiment. For example, a humanoid embodiment might involve two arms, two legs, and a head, while an animal has four legs and a head. Dependent of the shape of the body people will project different feelings onto the robot, meaning that the design of this body will make a difference in how it is perceived. While many studies have been done on how to shape a robot's body and face, less attention has been given to the question of what that body should be made of. With plastic pollution becoming an issue in our oceans (Eriksen et al. 2014) it is important to look for renewable and sustainable alternatives for manufacturing as robots become more commonplace. This change should not, however, mean a reduction in how effective socially interactive robots are at communicating. That means that there is need to make sure robots made of alternative materials to plastic are not perceived as less capable or uncomfortable for the user. For this reason, this study aims to figure out how social robots built out of different materials are regarded by people in terms of perceived competence, warmth and discomfort.

The research question this paper aims to answer is: *Does material choice change the perception of a social robot?* To answer this question a controlled study was run to evaluate the perceptual difference between the materials of wood, plastic, and fur.

THEORY AND RELATED RESEARCH

Robots as social entities
Human-robot interaction is becoming more of an everyday occurrence. Studies have shown that preferences for robot design vary for example between South Korea and Sweden (Lee & Sabanović 2014). This implies that what constitutes a positive interaction vary between places and people, and in turn implies that humans expect and want different things from their interaction with robots. Therefore, it becomes more important to consider design choices based on the desired social human-robot-interaction.

Robot taxonomy

To study robots as socially interactive entities there needs to be a system to sort and evaluate them based on their physical embodiment. Within biology, morphology is the study of the form and structure of animals and plants. Within robotics, morphology is the form of embodiment the robot takes. One study determined four distinct categories of robot morphology, that all have their strengths and weaknesses (Fong et al. 2003). These categories are *anthropomorphic, zoomorphic, caricature*, and *functional*.

Anthropomorphic

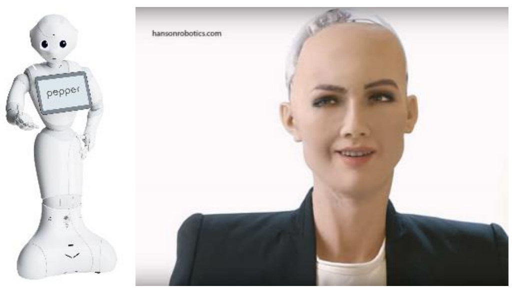

Figure 1. Pepper and Sophia, anthropomorphic robots.

Anthropomorphic, meaning humanlike, robots have a good balance between the illusion of sentience and functionality. However, they risk falling into the so called *uncanny valley* (Mori et al. 2012). This describes how humans have positive emotions towards humanoid figures until a certain point. If something looks almost familiar but not quite there can be strong feelings of disgust towards that embodiment. Examples include Pepper (Aaltonen et al. 2017) and Sophia (Retto 2017) pictured in figure 1. On this topic research has been done on how to best construct robotic faces, since the face is very important in interpersonal communication (Kalegina et al. 2018).

Zoomorphic

Robots imitating animals are helpful for establishing a human-pet relationship. These devices are mostly made to resemble household pets such as dogs or cats. Familiar animals create a sense of companionship but as their behavior is often familiar to people it may be difficult to mimic it well enough to avoid the uncanny valley of the animalistic variety (Ayesh et al. 2014). This issue is lessened with the use of more exotic animals that people are less familiar with such seals, but then it is possible to lose some of the closeness felt with pets (Shibata et al. 2009). Other examples include AIBO, a robot dog (Batliner et al. 2004).

Caricatured

Having less realistic embodiments can be a good way of avoiding the uncanny valley (Sebastian et al. 2015). The concept of a caricatured embodiment is based in animation, where it has been proven that an animated character does not need to be realistic in order to elicit an emotional response (Thomas et al. 1981).

Figure 2. Musicmouth, example of a caricatured robot.

Functional

Functional robots are designed to reflect the tasks it must be able to perform. Features are determined by the requirements of the device, whether those are cargo space or low production costs, rather than by the emotions or reactions the designer are intending to elicit from the user (Fong et al. 2003).

Materials and emotion

Many studies have been done on morphology (Fong et al. 2003) and general embodiment (Miller & Feil-Seifer 2016)of socially interactive robots. However, little work has been done on how material choice affect perception. As material plays a larger role in research done within other fields of study such as industrial design, it is possible to look at those fields and test whether the same is true for robotics. One study examined the link between the material a bowl was made of, and what emotions it evoked within the participants (Crippa et al. 2012). It was found that wood scored high on all positive attributes measured, like joy and satisfaction. It also scored low on the negative attributes, like disgust and fear. Plastic, on the other hand, generally scored towards the bottom on the positive and toward the top on the negative. It remains to be seen if the same applies to social robots, which are more complicated and probably elicit more complicated emotions than kitchen objects do.

Measuring emotional responses

To be able to measure intrinsic perceptions like emotions or opinions there needs to be a framework in place to help people give the research an understanding of their thoughts. The *Robotics Social Attributes Scale* has been developed to accurately measure social perception of virtual robotic faces (Carpinella et al. 2017). It has also been shown to be applicable to physical interactions (Pan et al. 2017). The scale supplies 18 items sorted into 3 categories that measure how participants view robots in social interactions, be they virtual or physical. These categories and their subcategories are displayed in table 1.

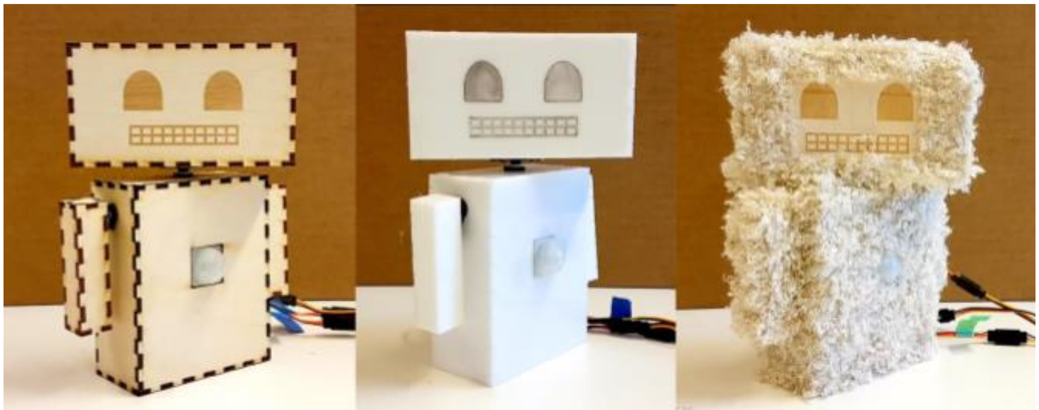

Figure 3. All three versions of the robot. From right to left: Wood, Plastic, and Fur.

Competence	Warmth	Discomfort
Reliable	Organic	Awkward
Competent	Sociable	Scary
Knowledgeable	Emotional	Strange
Interactive	Compassionate	Awful
Responsive	Happy	Dangerous
Capable	Feeling	Aggressive

Table 1. RoSAS items

METHOD

To determine if there are differences between materials, three similar robots were constructed; one of them in laser cut acrylic plastic, one in laser birch plywood, and one in laser cut plywood covered in synthetic fur. These three materials were chosen for two reasons; One: they were easy to work in, being both cheap and usable with a laser cutter. Two: based on previous research done it was believed that there would be a significant difference in the users perception of the robots (Crippa et al. 2012). That study showed that wood scored higher on positive emotions and lower on negative emotions than plastic. Fur was assumed to score similar to wood, due to both materials being perceived as organic.

Hypothesis for further study

Based on studies (Crippa et al. 2012) done in other fields of research my hypothesis is that materials perceived as organic such as wood and fur will be considered a more positive material than inorganic materials such as plastic.

Materials

The design was made to be easy to construct using a laser cutter, while still being stereotypically robotic. The first version was built in wood. A plastic version was constructed using the same blueprints as the wooden one, and later a second one was made of wood which was then covered in a synthetic furry fabric, see figure 3.

The final prototype robots were built using Arduino Uno, and possessed three degrees of freedom with MG90s micro servos in the shoulder joints and the neck. They had a motion sensor in the middle of the chest to allow them to react to the viewers movement, something that was not used when choosing to do the main study online using videos. Instead the robot was angled 45 degrees away from the viewer, then turned its head 45 degrees to face the viewer, raised the arm closest to the viewer and waved up and down three times.

Study design

Participants were presented with each version of the robots. After viewing a video or a live demonstration of the robot waving, they were given a survey to answer. The survey used a 9-point Likert scale to measure the responses to questions based on the Robotic Social Attributes Scale (RoSAS) (Carpinella et al. 2017).

Online survey

Using the Amazon Mechanical Turk 120 participants were selected. To account for order bias effects, the order in which the robots were presented was counterbalanced. They viewed a short video of the robot turning its head towards the camera and waving its arm, the same sequence of motions as in the live experiment [1]. They were asked to rate the version of the robot they just saw on the 18 aspects of the RoSAS. This procedure was repeated for the other two materials, with the order of the questions being changed between materials.

Live survey

A pilot study was performed on 10 engineering students from KTH in Sweden. The participants were selected by volunteering. The robots were displayed to the participants one at a time, and performed a simple sequence of movements consisting of turning its head towards the participant, then raising its arm and making a waving motion.

[1] Videos can be seen at https://goo.gl/vCJWJd, https://goo.gl/89QmNF, https://goo.gl/XXsTW2

After viewing this demonstration, the participants were given a paper survey to fill out, rating the robot on the 18 aspects of the RoSAS. This procedure was repeated three times for the three materials, with the order being changed between participants.

This pilot was run both as a pilot test for the main study, to see if the participants understood what they were supposed to be doing, and to examine if there were any differences in how people perceived robots in a live setting versus seeing a video on a screen.

Data analysis

After data collection, a Cronbach-alpha test was run on the subcategories of *warmth*, *competence* and *discomfort* to ensure that the RoSAS categories were accurate for this type of study. An average of each participant's score for each category was then calculated. On each of these categories a One-Way Repeated Measures ANOVA analysis was run. This test is an extension of a paired-samples t-test, and is used to determine of there are any significant differences between the means of a within-subjects factor. If the test found there to be a significant difference, custom contrasts were used to determine what those differences were and between which materials.

RESULTS

Online survey

Reliability test

120 participants were surveyed. A Cronbach-Alpha test was run on each category of the RoSAS to determine the reliability of the groupings. None of the items were determined to need exclusions, with *competence* scoring 0.926, *warmth* scoring 0.889, and *discomfort* scoring 0.884. This is considered highly reliable.

A boxplot determined that there were no outliers in the data gathered. My initial hypothesis was that *wood* and *fur* would score higher than *plastic* on the warmth portion of the items measured, while *plastic* would score higher in discomfort. This was tested using custom contrasts

Competence

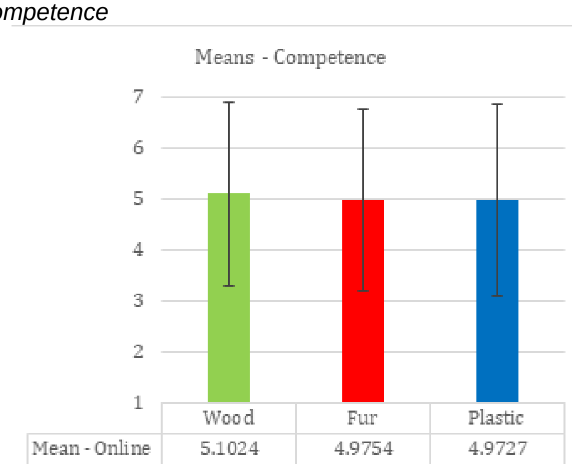

Figure 2. Competence means with standard deviations

Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, χ^2 (2) = 2.051, p = 0.359. The level of perceived competence was not found to be statistically significantly different between materials, F(2, 242) = 1.264, p = .284, η^2 = .010

Warmth

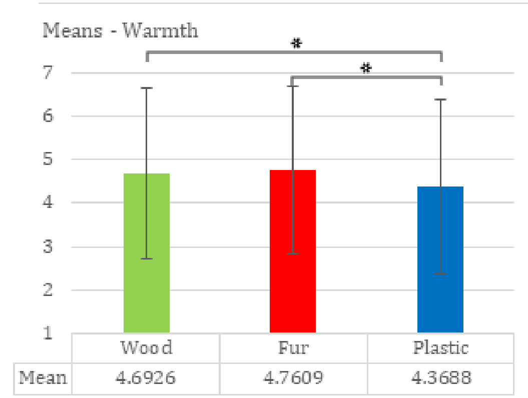

Figure 3. Warmth means with standard deviations. Asterisk indicates a significant difference between materials (p < .05).

Mauchly's test of sphericity indicated that the assumption of sphericity had been violated, χ^2 (2) = 14.423, p = 0.001. Therefore, a Greenhouse-Geisser (1959) correction was applied and was used to correct the one-way repeated measures ANOVA. The perception of warmth was statistically significantly different between the materials, F(1.797, 217.381) = 6.248, p = 0.003, partial η^2 = 0.049. Based on this difference a custom contrast was run to determine how they differ (shown below with Bonferroni adjustments to p and the confidence interval for running three contrasts).

		Wood vs Fur	Wood vs Plastic	Fur vs Plastic
Contrast Estimate		.068	.392	.324
Std. Error		.126	.130	.097
Sig.		1.764	.009	.003
95% Confidence Interval for Difference	Lower Bound	-.237	.076	.089
	Upper Bound	.373	.708	.559

Table 2. Warmth contrast results

There was no statistically significant difference between wood (M = 4.693, SD = 1.963) and fur (M = 4.761, SD = 1.925). Between wood (M = 4.693, SD = 1.963) and plastic (M = 4.369, SD = 2.007) there was a mean difference of 0.392 (95% CI, 0.076 to 0.708). Between fur (M = 4.761, SD = 1.925) and plastic (M = 4.369, SD = 2.0077) there was a mean difference of 0.324 (CI 95%, 0.089 to 0.559). This shows that robots made of wood and robots that have fur are perceived as warmer than robots made of plastic by approximately 0.4 and 0.3 points, respectively.

Discomfort

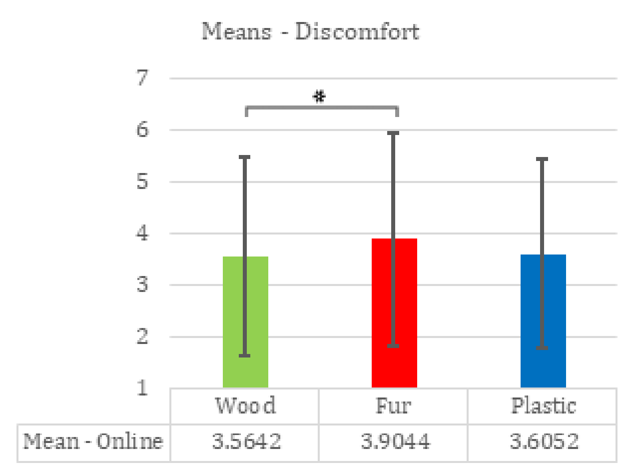

Figure 4. Discomfort means with standard deviations. Asterisk indicates a significant difference between materials (p < .05).

Mauchly's test of sphericity indicated that the assumption of sphericity had been violated, χ^2 (2) = 12.157, p = 0.002. Epsilon was calculated according to Greenhouse & Geisser (1959) and was used to correct the one-way repeated measures ANOVA. Perception was statistically significantly different between the materials, F(1.824, 220.733) = 4.861, p = 0.011, partial η^2 = 0.039. Running custom contrasts with a Bonferroni adjustment to compensate for running three contrasts yielded the following results.

		Fur vs Wood	Wood vs Plastic	Fur vs Plastic
Contrast Estimate		.340	.041	.299
Std. Error		.130	.099	.126
Sig.		.030	2.40	.057
95% Confidence Interval for Difference	Lower Bound	.026	-.199	-.008
	Upper Bound	.655	.281	.606

Table 3. Discomfort contrast results

There was a statically significant difference between fur (M = 3.904, SD = 2.053) and wood (M = 3.564, SD = 1.921) with a mean difference of 0.340 (95% CI, 0.026 to 0.655). Since p < 0.05 after the Bonferroni adjustment, this shows that there was a statistically significant difference between fur and wood, where fur was perceived as more discomforting than wood. There were no significant differences found between wood and plastic, or plastic and fur.

Demographics

While no demographical data on age group or gender was gathered in the study, based on the demographical data from Amazon Mechanical Turk for the dates data was collected on and the geographical location of the participants an educated guess has been made (Ipeirotis 2010). This was calculated using the demographics data from the specific dates data was gathered, which was 2018-05-18, 2018-05-20, and 2018-05-23.

Category	Percentage
Women	40.5%
Men	59.5%
Born before 1980	23.9%
Born 1980-1990	35%
Born 1990-2000	41.1%

Table 4. Demographic breakdown of online study

Physical survey

Through a Cronbach Alpha-test the categories from RoSAS were found to be accurately measuring the same dimensions with *warmth* scoring 0.880, *competence* scoring 0.899, and *discomfort* scoring 0.897. With a sample size as small as the one here (N = 10) it was not found appropriate to run a repeated measures analysis, so instead the means have been plotted alongside the means from the online study with error bars showing the standard deviation.

While it is not possible to draw a statistically significant conclusion based on the small sample size in the live study, the means are in general consistent with the online survey results, as described below.

Competence

There were two outliers found in the data gathered, participants 2 and 7. While the data points are considered outliers within the data set from the live study, they both fall within the means range from the online study. Since that study has a fairly large number of participants compared to this one, 120 vs 10, it was decided to include the outliers in the analysis. The reasoning is that with such a small number of participants it is quite possible that the data points would not be outliers had the number of participants been larger.

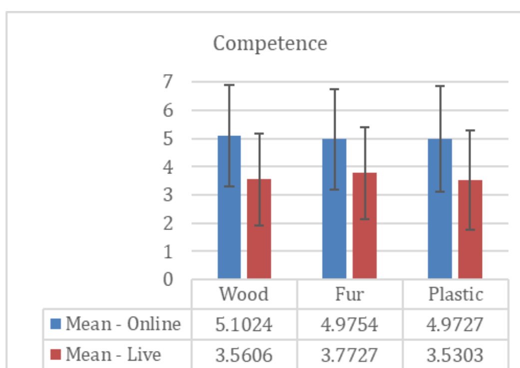

Figure 2. Comparison of competence means between the live study and the online study.

Warmth

Of note is the fact that while plastic scored lower than the other two in the larger online study, it had a higher score than wood and fur in the live study.

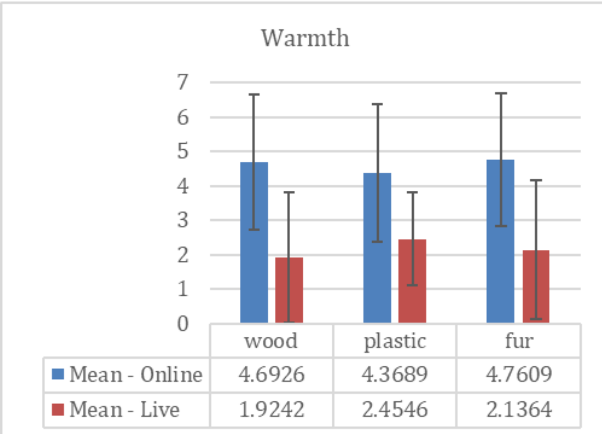

Figure 6. Comparison of warmth means between the live study and the online study.

Discomfort

One outlier was found, participant 10, but since that data point was found to be within the expected range of the larger study this outlier was not excluded from the results.

There are differences between the two studies here: Plastic was perceived as the most discomforting, compared to fur in the online study.

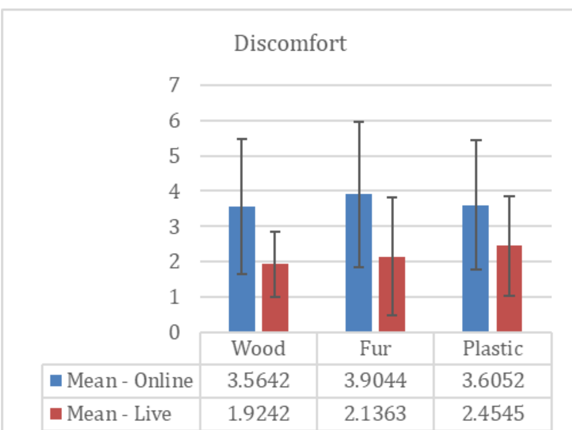

Figure 7. Comparison of discomfort means between the live study and the online study.

Demographics

The participants from the live study were engineering students at KTH Royal Institute of Technology, between the ages of 20 and 30. Out of the 10 participants who completed the study six were male and 4 were female.

DISCUSSION

To find out if there are differences in how people perceive robots made of different materials, two studies were conducted. Both involved asking participants to rate three versions of a robot, one constructed in wood, one in plastic, and one given a surface layer of a furry fabric, on the 18 aspects of the RoSAS (Robotics Social Attributes Scale). An in-person pilot study was conducted on 10 engineering students, and an online version had 120 participants recruited through the Amazon Mechanical Turk viewing videos of the three robots. The hypothesis was that materials perceived as organic would be considered more positively viewed than plastic, that has been the standard material for household robotics. While the smaller live study did not find anything definite, in part due to its small sample size, the large online survey found that wood and fur rated higher on the aspect of warmth than plastic did, and that fur was perceived as more discomforting than wood.

Lack of interaction

Most of the research referred to in this paper has been about socially interactive robots. The prototypes develop for this study, however, are too limited in their design to be considered socially interactive, since no interaction occurs between the participant and the robot. Despite this, the author believes that this study can be of relevance to researchers and designers. Since so much of a person's perception of objects, especially faces, occurs in the first milliseconds of interaction (Todorov 2013) it is believed that this research is valid for more interactive robots as well.

Implications

When starting this study, the author's hypothesis was that wood, and in turn other materials perceived as natural or organic, could be a good option for creating and building robots. The purpose was to examine if a more sustainable material choice than the traditional plastic could be an alternative for manufacturing as more robots and robotic devices are being produced. However, it was believed that this might not be a strong enough incentive to move to these alternative materials, so the thought was to examine if there are tangible benefits to using renewable materials. Wood was chosen from the beginning because it is a renewable material that is easy to work with. This theory turns out to be somewhat accurate. While no differences were found in the perceived level of competence the robots possessed, robots made of wood and fur were perceived as warmer than the plastic one, implying that certain aspects of the organic robots are viewed more positively. The fact that fur was considered more discomforting than wood could be because of the contrast with the somewhat anthropomorphic design and the zoomorphic trait of fur, leading to a schism since humans (and in turn anthropomorphic robots) do not tend to have fur. Another reason could be that people are not used to seeing robots made of a material that is so visually different from the more common ones of plastic and metal. Fur has a very different texture, and that could be affecting the results. A plotting of the means of the subcategories to discomfort for fur does indicate that strange and awkward score higher than the other subcategories. This could be a reason for fur being considered discomforting, but that would need further confirmation to be concluded.

Differences in results between studies

The fact that there were differences found between the two presentation methods (video vs. live) is interesting and worth exploring further given the low number of participants in the live pilot experiment. All three versions of the robot were rated lower on all aspects in the live study than in the online version. The reasons for this are not known, but it implies that either there are demographic differences between the two studies, or that people react differently to seeing a robot on video rather than in person.

One theory, based on a study done on what directions a robot can approach from to make sure the participants in comfortable, did show that while sitting at a table people are more comfortable seeing a robot approach on a screen rather than in person (Woods et al. 2006). Since the participants in the live study were sitting at the table the robots were standing on, this is a possible reason for the difference in results.

Another theory is that the participants in the live study had been primed to view robots a certain way, since right before performing this study they had completed another in which they interacted with a much more sophisticated robot. It is possible that this meant their expectations and presumptions were higher, and that they therefore felt a little disappointed by the limited interaction allowed by the robot prototype.

Limitations

Demographical data

The demographics of the two studies requires some consideration. Neither of them are necessarily representative of the wider population; both consisting of majority men between the ages of 20 and 30. Both groups, engineering students and registered workers on the online platform Amazon Mechanical Turk, also expressed interest in robots by signing up for a study of this kind. This indicates an interest in technology, again something that cannot be considered representative for a wider audience.

Robot design

The robot's design was meant to be caricatured, to avoid having to consider the known issues with uncanny valley present in anthropomorphic and zoomorphic designs. However, there is a suspicion that the design is read as more anthropomorphic than intended, considering the difference in discomfort between wood and fur.

CONCLUSIONS

The aim of the study was to determine if the same robot is perceived differently based on what material it is made out of, with the materials tested being wood, plastic, and fur. The study found a statistically significant difference in the perception of warmth between the materials of fur and plastic, as well as between wood and plastic in the online study, with fur and wood being considered warmer than plastic. This matches the previous research done on materials and emotion, even though that study was done within the field of industrial design with inanimate objects [source]. The online study also found a difference between wood and fur regarding discomfort, with fur being considered a more discomforting material than wood.

These results suggest that the selection of materials in robot design can influence people's first impression and subsequent emotions about social robots. Therefore, material is something to be considered in the design process for more than aesthetics or ease of construction.

Future research

Live vs Online studies

Every robot version had a lower mean on all aspects of the RoSAS in the live study than in the online version. While this could be attributed to the small sample size in the live study skewing the results it could be relevant to consider if there is a general difference in how people perceive robots in person versus on a screen. If there is in fact a difference that could have implication on how these types of studies are usually done.

Material choices

The fact that there are differences in perception between materials means that there could be reasons for designers and researchers to consider crafting robots out of alternative materials. However, this study would need validation to be considered in a wider context. A similar study would perhaps look at the interplay between material and design; it is possible to imagine that the preferred material changes if the design is to be zoomorphic. It would also be interesting to examine if the context the robot is supposed to exist in makes a difference in the preferred material, as well as looking at more materials than the three considered in this study. For example, if a robot is intended to be used in a domestic context it might be good if it considered warm and welcoming, which means that it should probably be built out of wood.

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