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The Pleasure Of Receiving A Head Massage From A Robot

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Abstract— **Tactile interaction is at the heart of human-robot relationships. The physical presence of the robot is what distinguishes human-robot interaction from human-virtual agent interaction. Although first attempts for tactile human-robot interaction have been made, robots are still far inferior to the abilities of humans in providing tactile experiences. This study investigates if a head massage given by others is more pleasurable than a massage given oneself and if a simple robot is significantly worse in giving a head massage. Furthermore we investigate if the physical experience with a robot changes the participants' attitudes towards robots. We ran a within-participants experiment with 18 subjects. The results show that receiving a massage by a human masseur is significantly more enjoyable than receiving it by a robot or by oneself. However, the participants displayed significantly more facial expressions of happiness in the robot condition. The participants did not significantly change their attitudes towards robots due their experience with the robot. We conclude that a robotic massage is a promising field for human robot interaction for further investigation.**

I. Introduction

The research field of Human-Robot Interaction (HRI) shares many challenges and opportunities with the field of Embodied Conversational Agents (ECA). Talking to a robot is not that different from talking to a screen based character. The problems of speech recognition, dialog management and social perception are similar. What sets HRI apart from ECA is the physical embodiment of robots. This embodiment has a profound impact on how robots are being perceived by users. For example, people seem to authropormophise robots differently than other forms of computer technologies [11]. Even more importantly, robots sense their environment, they can move around in the environment, and they are able to manipulate objects. To put it bluntly, a robot can bring you a beverage, a screen character cannot.

Moreover, the robot is able to physically interact with humans. They can touch, hug, kiss and hit humans. This tactile interaction is at the heart of human-robot relationships since it appears in the intimate interaction space. Most HRI studies refrain from interacting with robots at this short distance and focus on the private and public spaces. Salter, Dautenhahn and Boekhorst concluded that "Researchers are now beginning to recognize the importance of natural touch as a means of communication with a robot" [19]. Lee et al. showed that it is important for social robots to have a touch-input capability [12]. In their study, robots were evaluated more negatively if they did not have a touch based input capability. This interaction was based on the users touching the robot. The reversed interaction, meaning the robot touching the users, is even more important. Chen et al. showed that participants react positively to being touched by a nurse robot, in particular if the robot intended to clean the skin of the subject [3]. Nie et al. showed that humans preferred to hold a warm robotic hand when watching a horror movie compared to holding a cold robotic hand [15]. Cramer et al. showed that touching was perceived as being more appropriate for proactive than reactive agents [5]. Moreover, they found that "...the combination of touch and proactivity influenced whether people saw the robot as machine-like and dependable."

Robots have even been used for intimate interaction. DiSalvo et al. demonstrated a huggable robot [6] and Samani et al. developed a telepresence robot called Kissinger, that allows distant partners experience a kiss [20]. David Levy reviewed a large number of machinery that has been used for intimate interaction [13]. While these application areas might be of some interest, we believe that massages are an application field that may appeal to a larger number of users and that is certainly less controversial. Already in the year 2005, 15% of all Japanese households owned a massage chair [22] such as the model shown in figure 1.

Fig. 1. A Panasonic massage chair

While the massage chair technology has developed considerably in the last years, they still are not as good as a human masseur. The tactile sensitivity of human masseurs and their professional training makes them superior to any current machine. But there is possibly a second reason why human masseurs are better. Their presence evokes the social

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facilitation effect which makes patients endure even painful experiences [1]. Robots are being perceived as social actors [21] and are also able to evoke this effect. We speculate that a robotic masseur could be more successful than massage chair. While users might quickly adjust the dial on their massage chair to avoid discomfort, they might endure such a massage from a robotic masseur.

First steps towards creating massage robots have been made. Kang et al developed a massage robot that uses a tapping type of massage on humans' backs [4] and Jones and Du used a PUMA 562 robot to provide basic massage manipulations for medical therapy [10]. Panya et al. developed force control algorithms for a multi-fingered robotic hand for a massage [18]. The robots' abilities to sense the human body can further be extended through sensor networks and cameras. This would allow the robot to adapt its movements even further. However, for most households this might be too expensive and too complicated to setup. The studies mentioned above focused on the development of the control algorithms necessary for the operation of the massage robots and none of them evaluated their system with a controlled user experiment.

In this study we focus not on the development of control algorithms, but on how a massage given by simple robot is perceived. This is even more important since for certain types of massages that are being perceived as more pleasurable when performed by another actor. It is well documented, for example, that you cannot tickle yourself [2]. Furukawa, Kajimoto and Tachi developed the Kusuguri system to overcome the problem of remote tickling by using smart phones and vibrators [8]. Their study provides a first clue on robotic tickling devices.

We focused on the robot giving a head massage using a device that is produced in Australia and sold by the name "Happy Head Trip" in the USA (see Figure 2). The produce is sold worldwide under different names. The peculiar name of the device already hints at its effect. From our personal experiences we would describe the device's effect as being similar to tickling. It does often cause goosebumps and shivers. The scalp is a surprisingly sensitive body area and over 100 patents have been filed for scalp massage devices. The Panasonic company already started testing a head care robot in a Japan in 2012 that washes and massages the users' scalp [17]. They intend to deploy the system in hair saloons and elderly homes. Interestingly, the hair saloon owner indicated that many male customer like a "strong" massage. This might mean that the robot has difficulties adjusting the strength of its fingers.

The massage device in our study overcomes this practical problem. The movements of a simple robot are not necessarily well controlled and the head massage device functions as spring between the robot's hand and the scalp of the participants. Even if the movements of the robot might be slightly rough, it does not cause any discomfort for the users. A scalp massage using the head massage device is therefore a good starting point for testing the effects of a simple robot giving a massage.

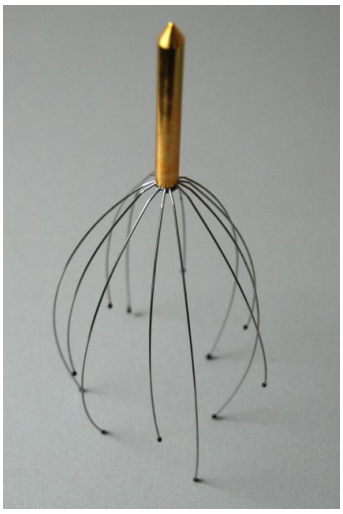


Fig. 2. The Happy Head Trip massage device

Tactile interaction with a robot might also have an influence on the attitude users have towards robots [9], [5]. Negative attitudes toward robots can decrease perceptions of anthropomorphism and closeness of the relationship between the human and robot [5]. We therefore investigated if receiving a massage from a robot might change the attitudes of users towards robots.

Based on the arguments above we define the main research questions of this study as:

1) Do humans perceive a head massage received from a human masseur as more pleasurable than a head massage performed by themselves?
2) Do humans perceive a head massage received from a simple robot differently in terms of pleasure than a head massage done by themselves?
3) Do humans change their attitude towards robots after they had a physical experience with them?

This study was approved by the Ethical Committee of the University of Canterbury with the reference number HEC 2012/19/LR-PS. All participants signed a consent form and a video consent form prior to the start of the experiment. The participants were informed that they could abort the experiment at any time without any negative consequences.

II. Method

We performed a within subjects experiment in which the independent variable *masseur* was either the subject him/herself (self) or the experimenter (human) or the Nao robot (robot). A within participants structure of the experiment was the preferred choice to compensate for individual differences in the appreciation of head massages. Some participants might have a more sensitive scalp than others. The assignment of the participants to one of the six possible sequences of conditions (shr, srh, hsr, hrs, rsh, rhs) for self (s), human (h) and robot (r) was counterbalanced.

A. Measurements

To measure the pleasure of the massage experience we used the "Massage as Pleasant" subscale of the Attitudes Toward Massage (ATOM) scale [14]. We only had to change the tense of the questions, since the original ATOM scale asked about a general attitude, while we had to ask about a specific prior experience. This scale consisted of five questions on a five point likert type scales in which 1 denoted "strongly disagree" and 5 denoted "strongly agree".

1) I liked to be massaged
2) Receiving massage is relaxing
3) Receiving the massage improved my mood
4) Receiving the massage made me nervous (reversed item)
5) I liked to be touched by the masseur

We took the average of the five items to calculate the dependent variable *pleasure*. A high value on the ATOM scale therefore indicates a high level of pleasure. In addition, we measured the participants' view on robots with the Negative Attitude Towards Robots Scale (NARS) [16]. The NARS scale consists of 14 items in three sub scales that each are being rated on a five point likert type scales in which 1 denoted "strongly disagree" and 5 denoted "strongly agree". A high value on any of the three NARS sub scales indicates a high negative attitude towards robots. We also asked the participants about their prior experience with robots. In addition we video recorded the participants to be able to analyze their facial expressions during the massages. The video camera was placed slightly aside in front of the participants so that it could record the facial expressions of the participants. All participants were fully aware of the presence of the video camera and its recording function. They were to specifically told that their facial expression would be analyzed, but rather that the overall session would be recorded.

B. Participants

We had 18 participants at the age between 18 and 49 (mean 25.6) of which 7 were women and 11 were men. Most were associated to the University of Canterbury, New Zealand. Twelve participants never interacted with a robot before, five reported they had interacted 1-10 times, and one reported that he interacted more than 10 times with a robot. The participants received cookies as a reward for their effort.

C. Setup

The experiment took place in a 3x5 meter room. The participants were seated on a chair. The robot was standing behind them on a box that was placed on a table (see 3(b)). This was the only position in which the robot was able to reach the scalp of the user. For security reasons we strapped the NAO robot to the box and the box to the table. The robot could therefore not lose balance and fall onto the participants.

The robot held the massage device in its left hand. The experimenter was seated behind the participants to control the robot. This prevented that the participants might have been under the impression that the experimenter is controlling the robot. The experimenter, in fact, only started the robot action sequence and supervised the motion. The movements of the robot action sequence was designed using the Choreograph software prior to executing the experiment. The experimenter would have aborted any action that might have made the participants feel uncomfortable. Fortunately, this was never necessary.

For the human condition, the masseur stood behind the participants as shown in Figure 3(a). For the self condition, the participants were given the massage device. The massage devices were washed with soap and water after every participants.

The questionnaires were administered using an iPad. We used the Qualtrics service to design, present and collect the questionnaires. The participant could remain in the chair throughout the whole experiment.

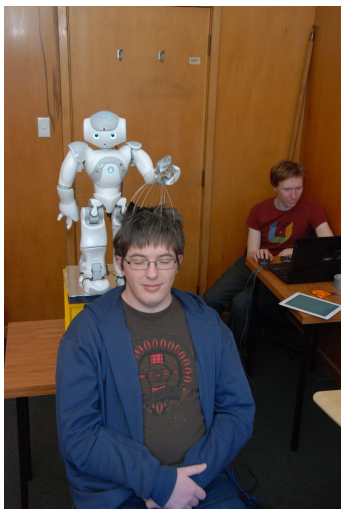
D. Process

The experimenter welcomed the participants and asked them to sit on a chair. Once the participants were seated, the experimenter provided an iPad that contained the introduction and consent form. When the participants agreed to the consent form, the participants handed the iPad back to the experimenter. The experimenter then explained to the participant the order of the conditions they will experience, and that after each condition, they will be asked to fill out a short survey. Once this has been explained, the experimenter passed the iPad back to the participants, and asked them to fill out a demographic survey and the NARS survey. The NARS survey consists of three sub scales: Negative attitude toward situations of interaction with robots (e.g. I would feel nervous operating a robot in front of other people), Negative attitude toward social influence of robots (e.g. Something bad might happen if robots developed into living beings) and Negative attitude toward emotions in interaction with robots (e.g. I feel comforted being with robots that have emotions). After the participants finished filling out the two surveys, they handed the iPad back to the experimenter.

The experimenter then provided to the participants the head massage device so that the participants may familiarize themselves with the device. Once familiarized, the participants handed the head massager back to the experimenter. The experimenter then instructed the participants on which of the three conditions the participants would be exposed to first.

For example, in the masseur, self, robot ordering, the experimenter instructed the participant that the masseur will give a head massage to the participants for around 45 seconds. A stop watch was used to time the session. This duration was selected to avoid any strain on the arm. If the participants had to hold up the arm much longer, it might have caused some discomfort. The masseur asked if the participants are ready. If the participants respond in the affirmative, the masseur then began the massage. Once the massage was completed, the experimenter provided the iPad back to the participants and asked them to fill out the first pleasure questionnaire. After the question had been

(a) Human



(b) Robot

(c) Self

Fig. 3. The Masseurs Conditions

completed, the experimenter took the iPad away from the participants and instructed the participants that it is now time for the self massage.

The experimenter instructed the participants to massage their own head with the massager for around 45 seconds and gave the head massage device to the participants. The experimenter said to begin when ready. The experimenter used a stopwatch to track the time of the massage. When completed, the experimenter took the head massage device away from the participants, and then gave the participants the iPad with the second pleasure questionnaire. After the question has been completed, the experimenter took the iPad away from the participants and instructs the participants that it is now time for the robot massage.

The experimenter asked the participants to adjust the height of their chair and the experimenter adjusted height of the robot so that the head massager is situated directly above the head of the participants at about 2-5cm distance from the head. The experimenter then asked if the participants are ready for the head massage. If the participants responded in the affirmative, the experimenter initiated the robot massage application. The robot said to the participants "Today I will give you a head massage. Are you ready for the massage?". And then the robot began the massage, which lasted around 45 seconds. The robot's movements were designed to mimic the normal movements of the masseur. It consisted of up and down movement and circular movements in the down position. The masseur used the same movement patterns. Once the massage was complete, the robot announced to the participants "I hope you enjoyed the head massage".

The experimenter then handed the iPad back to the participants and asked them to fill out the final questionnaire. The experimenter also explained that there will be one more NARS survey after the massage questionnaire. Once the questionnaires were complete, the experimenter took the iPad from the participants and gave a chocolate biscuit as a thank you for the participants time. The experimenter explained to the participants that the experiment is now over, and the experimenter also debriefed the participants about the experiment and its purpose. The experimenter asked whether the participants had any questions. If the participants did not, then the participants were asked to leave through the door they came in from. The whole experiment took around 25 minutes.

III. Results

We performed a reliability analysis on the NARS questionnaire items. The questionnaire was administered twice, once before and once after the experiment. Before the experiment the Cronbach's Alpha for the interaction sub scale was 0.176, for social 0.468 and for emotion it was 0.462. This is far below what other studies previously reported. After the experiment the Cronbach's alpha for interaction was 0.604, for social 0.800 and for emotion 0.810. We also performed a reliability analysis of the pleasure subscale of the ATOM questionnaire. This questionnaire was administered three times, once for each condition. For the human condition the

Cronbach's alpha was 0.851, for the self condition it was 0.822 and for the robot condition it was 0.872.

We performed a paired samples t-tests to investigate if the participants had changed their attitude towards robots. The three components of the NARS questionnaire (interaction, social, emotion) were the within participants variable. There was no significant effect for interaction [t(17)=-0.291, p=0.775] and emotion [t(17)=-1.990, p=0.228]. The social factor was approaching significance [t(17)=-1.990, p=0.063]. The mean scores for all three NARS factors are shown in Figure 4.

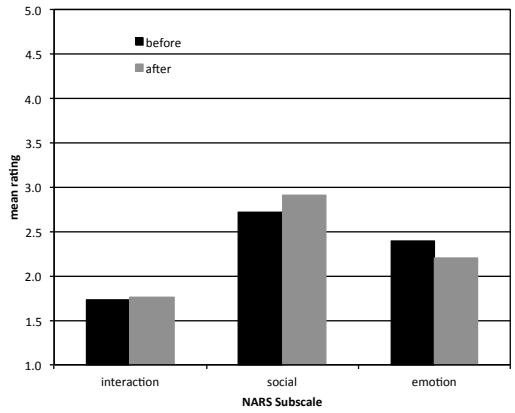


Fig. 4. Mean NARS ratings before and after the experiment

We performed a repeated measure ANOVA with masseur being the within participants variable (self, human, robot) and pleasure being the dependent variable. The masseur had an overall significant effect on pleasure (F(2,34)=8.521, p=0.001). The Bonferroni corrected pairwise t-tests revealed that human masseur (M=4.122, Std.Dev.=0.732) was rated significantly higher than self (M=3.70, Std.Dev.=0.933, p=0.026) and robot (M=3.50, Std.Dev.=0.918, p=0.01). The mean scores for the three conditions are shown in Figure 5.

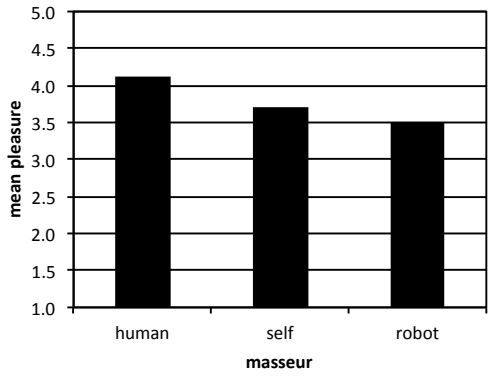


Fig. 5. Mean pleasure rating across the three conditions

Two expert raters that were part of the research team watched the videos and counted how often the participants showed the six basic facial expressions [7] of happiness, sadness, anger, disgust, fear and surprise in each of the three conditions. Prior to the coding, the raters watched three sample recordings to establish a baseline. The raters then separated and coded the videos independently. The raters were fully aware in which condition each participant was. The two raters did not observe any expressions of anger or sadness and there were also only very few observations of fear. For a few conditions the raters were not able to code any facial expression since the participants had either turned away from the camera or hair concealed their face. This situation was recorded as missing data for the analysis. The raters did also not count any facial expressions that were not directly related to the massage or that happened before and after the massage. The participants might, for example, expressed a certain thought during the experiment.

We performed a reliability analysis on happiness, disgust, surprise and fear to check to what degree the two raters agreed. The intraclass correlation coefficient for happiness was 0.579, for disgust it was 0.796, for surprise it was 0.133 and for fear it was 0.566. Except for surprise, this gave us sufficient confidence in the ratings to use the average of both raters in the following analysis.

We performed a repeated measure ANOVA in which the masseur was the independent variable (self, human, robot) and the facial expressions of happiness, disgust, surprise and fear were the dependent variables. There was only a significant difference for happiness (F2,24)=6.559, p=0.05). A pairwise Bonferroni corrected t-test revealed that the participants expressed significantly more happiness in the robot condition (M=3.50) than in the self condition (M=1.07, p=0.008) or in the human condition (M=2.29, p=0.018). The mean frequencies for the four emotions in the three masseur conditions are shown in Figure 6.

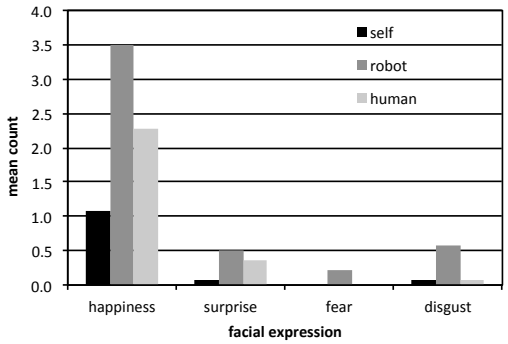


Fig. 6. Mean count of emotional facial expressions across the three conditions

IV. Discussion

It is not surprising that the robot was not able to give a head massage that was as good as the one received from a human masseur. The human's ability to sense and act is largely unmatched. The superiority of humans is not limited to this study. Would a human control condition be

included in most HRI studies then we would most of the time have to admit that, despite all our efforts in developing robots, humans are still the better butlers, companions, and conversation partners. But we shall not despair over this obvious disadvantage. The robotic development is still at its beginning and we shall not dismiss technologies in their early stages. Even Apple's first iPad, the Apple Newton, was hardly usable and it failed in the market.

The main reason for the robot's limited massage skills are its lack of a visual or tactile feedback loop. The robot was not able to adjust its massage to the characteristics of each participants. They were different in height, skull size, hair length, and hair strength. Moreover, some participants appeared to have a much more sensitive scalp than others.

The Cronbach's alpha for the NARS questionnaire sub scales was very low before the experiment and increased dramatically after the experiments. This indicates that many participants did not have strong and consistent opinion about robots, probably due to the fact that they had barely interacted with them before. We therefore have to treat the results of the analysis of the NARS data with some care. The results seem to suggest that the participants did not change their attitude towards robots due to their experiences in this experiment. Most participants had only very little prior experience and given the limited abilities of the robot, it was not able to trigger any fundamental changes. However, the video recorded several instances in which the participants praised the robot. One participants described the massage as very tender and another explained that the robot was certainly better at it than himself. No participant uttered a negative or positive response in any of the other conditions. We interpret this result as that the participants might have had a very low expectation of the robot. They were then positively surprised about the quality of the massage, although it did not reach the level of a massage given by a human masseur.

We feel encouraged that the massage of such a simple robot was not rated as significantly worse than a massage given by the participants themselves. Moreover, the participants expressed happiness significantly more often in the robotic condition compared to the other two conditions. It also appears that the participants showed in general many more facial expressions in the robot condition. This indicator is of particular importance, since the facial expressions were involuntarily. The participants expressed a direct experience. For the questionnaires, they had the time and opportunity to rationalize their responses.

Our results show that a massage received from somebody else is perceived as much more pleasurable. And this is where the great potential of a robotic masseur can be found. There is a true potential that a robotic head massage will feel much better than a massage done oneself.

A. Limitations and future work

This study does have certain limitations that restrict the interpretation of the results. Firstly, we did not give a muscle massage. While head massages certainly do have a relaxing effect, they do not result in muscular tension relief. Muscular tension is probably the more important application field, but given the limitations it is predictable that the robot would not have been able to perform a useful muscular massage. We therefore have to consider this study only as an initial indication.

Secondly, the massage was limited to a relatively short duration due the practical constraints of running a within participants study. It is conceivable that a ten minute massage might have a stronger effect. However, the NAO robot turned out to overheat very quickly. After two participants, the robot had to shut down to be able to cool off.

We also make the assumption of a direct relationship between the facial expression and the internal state. We assumed that if participants smiled, they felt happy. This direct mapping may be naive, since social display rules mediate the usage of facial expressions. The discussion about the exact mapping of facial expressions and internal states go beyond the scope of this paper and for the time being we accepted the potentially naive mapping.

For a future study we are interested in extending the massage duration and to use sensors, such as the Microsoft Kinnect, to better be able to adjust the robot's movements to the participants.

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