Simple Looks, Complex Moves:
Why the use of Humanoid Robots is promising for Human-Robot Interaction

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Table of Contents

Abstract

In the future robots will participate in society as autonomous creatures so humans have to get used to their presence. A way has to be found to achieve a positive relation between a human and a robot. To interact with humans robots do not necessarily have to resemble other human beings, this could even have negative consequences for the relation between humans and robots. The Uncanny Valley theory describes the phenomenon that very human-like robots elicit fear in humans. This negative reaction might occur when the human notices features of the robot which are not human, for example robot skin which feels like rubber. This is called the ‘Zombie’-effect. Another explanation is provided by Terror Management Theory, which assumes that robots actually are reminders of death to humans. Framing theory offers a third explanation for uncanny feelings in the human. During exposure to a robot, accidentally the frame ‘human’ and not the frame ‘robot’ is activated in the human. The human again gets shocked from robot features which depart from the ‘human’ frame.

Uncanny effects exist for robot appearance but even more strongly for robot motion. Unfortunately appearance is better developed and more human-like in today’s robots than motion. The latter component is assumed to be most important in human-robot interaction making robot appearance secondary. Robots should move in a natural and reactive way, but their appearance may be simple or in other words iconic. An experiment was conducted to assess the effects of robot motion. Human subjects were presented with either a moving or a still humanoid robot Nao and had to rate it in terms of human-likeness and liking. No effect of robot motion was found, presumably because of too small group sizes or a weak experimental manipulation. However, there was a significant relation between the Nao´s human-likeness and the extend to what it was liked by the subjects. This adds support to the assumption that human-likeness of robots has a positive influence on human-robot interaction. The question whether appearance or motion has to be human-like could not be answered by this experiment so more future research is needed.

1. INTRODUCTION

Today robots already own a fixed place in most industrial settings, taking over tasks which in the past have been executed by humans. Currently also much effort is put in building robots which could autonomously interact with humans. This interaction possibly could take place in a social context where the robot might be able to evoke an affective reaction in the human. Besides its effect on the human, a robot itself might also be able to show emotions.

No matter in which of the many diverse directions the relationship between robots and humans goes, it is an established fact that technology and with it robots are continuously getting more important in human society. Be it in a decade or a century, humans necessarily have to get used to the fact of sharing their daily life with a robot, so attempts have to be made to obtain beneficial human-robot interaction. Good human-robot interaction for example could be when the human accepts the robot as an interacting partner and understands how to communicate with it. The robot in turn has to perceive the actions of the human and react to them in an appropriate manner. The most widely used attempt to achieve good human-robot interaction takes interaction between two humans as a model for designing robots. The concept behind this is that human-like looks and behavior should make interaction more intuitive for the human so he does not require learning how to deal with the robot (MacDorman, 2006a). Unfortunately there is at least one problem lurking behind this conceptualization, making it likely to fail: Robots are no humans, neither in regard to their looks nor their behavior. In the past and present, many attempts are made in building human-like robots. Concerning robot appearance designers already succeeded in creating extremely human-looking robots, called androids. Presented for a few seconds many androids are even indistinguishable from real human beings (MacDorman, 2006a). Most androids like Hanson´s PKD or Ishiguro´s Geminoid HI-1 are perfect resemblances of the outer appearance of the models after whom they are build. This perfectly elaborated android-look evokes expectations about the robot´s behavioral capacities in the human counterpart, for example that besides human-like appearance the robot also possesses human-like intelligence (Dautenhahn, 2002) or motion. These expectations are not fulfilled because in the present robot appearance is much more evolved than robot intelligence or motion, so the robot is not acting as human-like as it looks. An example could be an android lacking chest contractions which should resemble breathing. These behavioral shortcomings are then at the expense of the naturalness of the interaction or even worse could elicit feelings of unease or fear in the human. The latter part is explained by Mori´s Uncanny Valley theory (1970) which states that robots which are very human-like but display slight deviations from a real human seem unfamiliar and strange to humans and remind them of sickness or death.

From robot appearance and motion, the latter one seems to be more important as motion is a very strong elicitor of anthropomorphic attributions (Heider & Simmel, 1944) which ultimately could end up in perceiving the robot as human-like. Paradoxically at present robot appearance is developed more thoroughly, maybe because its development is simpler. Beneficial human-robot interaction could be achieved by making the developmental discrepancy between robot appearance and robot motion disappear, which means bringing robot motion up to the same level of human-likeness as robot appearance. Because of the already mentioned possibility of negative affective reactions by humans, androids with human-like appearance but artificial motion could be problematic in human-robot interaction research. Instead another approach has to be adopted to improve motion: Going back to humanoid robots. Humanoids are robots that have organic, round forms and consist of a torso, limbs and a face with few expressive features. They differ from androids in appearing less human-like at first sight, making them immediately recognizable as robots. A big advantage of humanoid robots is that because of their lack of human-like appearance little failures in behavior will be more readily accepted by humans (Bartneck, Kanda, Ishiguro & Hagita, 2007). At first sight humanoids are directly perceived as robots, but androids could leave some doubts.

Concluding from all above mentioned aspects, this paper aims at investigating on the hypothesis that humanoid robots lacking human-like appearance could yet be perceived as human-like through their motion. If this hypothesis is confirmed a first step is made in guiding the conceptualization of carrying out future human-robot interaction research, namely by using humanoids. To introduce the topic in more depth literature is reviewed describing the Uncanny Valley phenomenon with its possible causes and criticism and the influence of robot appearance and motion. Then the experiment with the humanoid robot Nao is discussed which aims at confirming the hypothesis.

2. THE UNCANNY VALLEY

Mori´s (1970) Uncanny Valley theory measures the amount of familiarity a human feels towards a robot. How familiar the robot appears to the human strongly depends on the human-likeness of the robot´s design, concerning appearance as well as motion. The relationship between human-likeness and feelings of familiarity is described in a curve (Fig. 1).

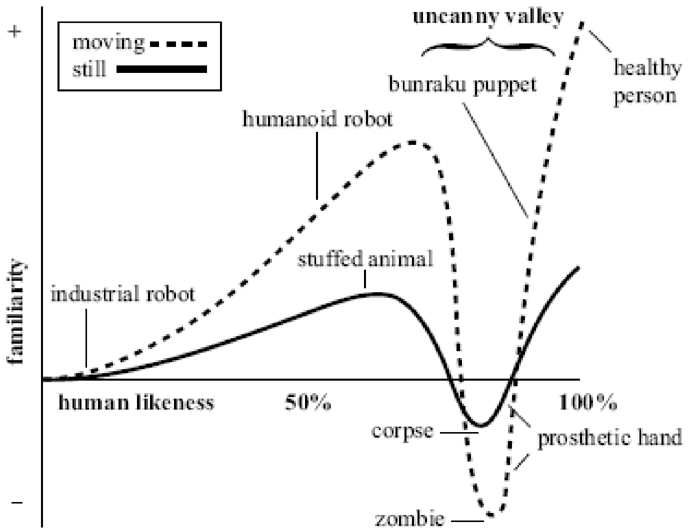

Fig. 1: The Uncanny Valley (MacDorman, 2006b).

Near the zero point an industrial robot is located which is absolutely not human-like and therefore does not cause any feelings of familiarity in humans. As one goes further on the x-axis which represents human-likeness, feelings of familiarity rise almost in a linear way (Mori, 1970). Humanoid robots are located at a point where 50 percent human-likeness is reached, which makes them already appear quite familiar to humans. These heightened familiar feelings possibly arise because humanoids possess a torso, limbs and a face with minimal expressive features. When the curve passes the point of approximately 80 percent human-likeness it reaches a critical point. From now on familiar feelings do not increase anymore, but unexpectedly drop beyond zero. This dropping of the curve is called the Uncanny Valley. At its deepest point creatures like zombies or corpses could be located, which are associated with sickness or even death. This seems paradoxical as robots found in the Uncanny Valley are more human-like than humanoids but are approached with strong negative affect. As the amount of human-likeness comes closer to 90 percent familiar feelings rise again and at perfect (100 percent) human-likeness these feelings even exceed the amount of familiarity at the first top just before the Uncanny Valley occurs.

In the Uncanny Valley theory, the effects of robot appearance and robot motion are discussed separately. Both have the same influence on a human´s feelings, but the effect of motion results in an exaggerated pattern of the curve. The reason behind this effect lies in a human´s heightened sensitivity for minor variances in movements (Mori, 1970). Human motion owns very specific spatiotemporal characteristics and if these are changed the slightest bit, motion immediately might not be accepted as human anymore. An expression which changes in a natural acceleration from neutral to smiling is evaluated as appearing pleasant, however the same expression looks repulsive if the speed of the acceleration is heightened (Blow, Dautenhahn, Appleby, Nehaniv & Lee, 2006). Because humans are so delicate concerning human-like characteristics (especially motion), Mori advises robot designers to stick to the first top of the Uncanny Valley curve. If one tries to make robots more natural exceeding 70 percent of human-likeness it would be almost certain that these robots would end up in the Uncanny Valley (Mori, 1970). As this statement forms a major restriction to current conceptualizations of robot design there is some criticism on Mori´s theory. The Uncanny Valley theory indeed possesses some major limitations, the greatest one being the fact that it is was never based on empirical data (Hanson, Olney, Pereira & Zielke, 2005). Furthermore, Hanson et al. (2005 ; 2006) suggest design methods for robots which can avoid the Uncanny Valley phenomenon, no matter how human-like the robot is. Their design suggestions are discussed in depth in the author´s Bachelorthesis, which is included in the references.

2.1 Why is there an Uncanny Valley?

The so called ‘Zombie-effect` (Dautenhahn, 2002) provides one possible explanation why people might develop negative emotions as fear or disgust towards very human-like robots. At first sight these very human-like robots appear pretty much alive but when a human gets in closer contact with them or is exposed to them for a longer period of time, all of a sudden he discovers minor flaws in the robots´ design. These flaws make the robots differ from the human and the human realizes that the robots are not alive as he thought so at first sight (Dautenhahn, 2002). This realization is accompanied with surprise loaded with negative affect. The human´s negative emotional reaction could be explained with Terror Management Theory, which states that robots, especially androids, might be unconscious reminders of death (Greenberg, Pyszczynski & Solomon, 1986). Every living organism has the instinct to survive or in other words avoid death, but humans are the only species who know that death is unavoidable. To handle this knowledge, humans have developed several defense mechanisms which should prevent them from thinking about dying (Pyszczynski, Greenberg & Solomon, 1999). An example of those defenses is standing by their own cultural worldview.

MacDorman (2005) confronted participants either with an image of an uncanny looking android or with a neutral control image. The participants had to rate two foreign students in terms of liking and expertise. Both students talked about their experiences in the participants´ home country, whereby one student commented in favour of the country and the other against it. Results showed that participants who were confronted with an uncanny android beforehand, much stronger preferred the foreign student who praised their home country than did the control group who saw a neutral image (MacDorman, 2005). This result showed that uncanny androids are capable of eliciting defense mechanisms which according to the Terror Management Theory should prevent them of getting too scared of death. In conclusion this means that some androids might be reminders of death and therefore are located deep in the Uncanny Valley.

Another possible cause of the Uncanny Valley lies in framing theory (Minsky, 1975). Frames are knowledge structures wherein many terms are related to one central topic. Furthermore, as all these terms share one common topic which they belong to, they are also interrelated with each other. An example would be the frame concerning the topic “restaurant” surrounded by terms like “drinks”, “food” and “tables”. In addition one could see relations between the particular terms, as food and drinks often are served together and most often both are standing on a table. When a person is confronted with a certain familiar topic the whole frame gets activated involuntary. This frame guides the the person´s opinion and expectation about the situation where he is about to encounter this topic (Bartneck et al., 2007) For robots two different frames could be activated depending on their amount of human-likeness. If a person sees a technological looking robot, for example a humanoid, the frame ‘robot’ is activated. When this robot possesses human-like features, which are not included in the ‘robot’ frame, they attract attention and the human will be positively surprised (Bartneck et al., 2007). However, when a person is confronted with a very human-like robot, for example an android, accidentally the wrong frame ‘human’ gets activated and unfortunately the less human-like features (for example artificial skin feeling like silicon instead of human tissue) stand out. The consequence is the same as mentioned in the ‘Zombie effect’: The human gets negatively surprised or even shocked, because the whole picture reminds him of a sick or dead human (Etcoff, 1999).

3. ROBOT APPEARANCE

First of all motion is assumed to be a very strong elicitor of anthropomorphic depictions towards robots (Heider & Simmel, 1944) and therefore of major importance for human-robot interaction research, but there could not be any moving object without having an outer appearance. Furthermore appearance is almost always the first piece of information one gets at an encounter (Hogg & Vaughan, 2005), and this information triggers unconscious cognitive processes which activate prior knowledge. So very often it is a robot´s appearance on which at least its first evaluation is based.

Mori (1970) gave in his Uncanny Valley theory the advice to equip robots with less human-like looks to prevent humans from having too high expectations of the robot or being shocked by the robot´s appearance. A new aspect of the influence of outer appearance was raised by Dautenhahn (2002): The outer appearance of a robot determines how well the human can identify with the robot. This idea origins from comic design, where it became clear that people were more likely to ogle with the simple drawing of Charlie Brown than with a detailed portrait of Marilyn Monroe (Dautenhahn, 2002). Possibly findings about comic design could be transferred to robot design as robots also are some kind of artificial creatures. The design space of cartoon faces can be represented in triangle form and knows three corner points: Realistic, abstract and iconic (Fig. 2; McCloud, 1993).

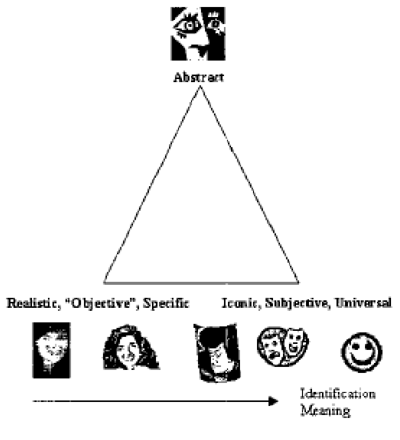

Fig. 2: Design space of comics (Dautenhahn, 2002).

Realistic appearance is equivalent with a resemblance of reality, with all features shown. Everyday examples are a photo or naturalistic art as well (Blow et al., 2006). A realistic appearing robot would be an android, which imitates human looks. An object possesses abstract appearance when the inward meaning of the object is shown by its look (Blow et al., 2006). An example of abstract robot design could be Star Wars´ R2D2. For human-robot interaction research abstract robots are not interesting as they either totally lack expressive features or their features are too distorted to create any expressions which could be meaningful to humans. Iconic appearance is a reduced resemblance of reality and especially in the face the focus lies on a few expressive features. Features which are not important for certain expressions are simply omitted in design thereby focusing on the remaining parts. The simplest example which one encounters in every internet chat room would be “ :) ”. An example of iconic robot design would be Aldebaran´s humanoid robot Nao (Fig. 3).

Fig. 3: Iconic design: The humanoid robot Nao (www.aldebaran-robotics.com).

As a humanoid, Nao has a head with a face, a torso and limbs which are all formed in round organic shapes. Its appearance is iconic because it lacks fine details like a nose or mouth or toes. On the one hand these details would make the Nao look more human-like but on the other hand they would not add anything important to its expressive ability and also not to its acceptance by humans. Although an iconic robot is not looking very human-like acceptance could be great. As one takes the two design categories realistic and iconic, people are much more likely to identify with a reduced, iconic appearance. The more iconic an object looks, the more universal it appears thus the more people it could represent, including us (Blow et al., 2006). Realistic appearance is always bound to one specific person whereby iconic appearance can represent a lot of people through reduction to basic features all humans share. If it would be possible for the user to identify with an iconic robot, some kind of emotional bond between him and the robot could develop. Getting attached to a robot is assumed to be very beneficial for human-robot interaction.

Iconic appearance offers another great advantage for robot design: It provides robots with a distinct appearance which does not already exist in nature (Dautenhahn, 2002). As this appearance is unknown to humans, they will have few if any expectations about the behavior the iconic robot will show which prevents the humans from disappointment and frustration. An advantage of iconic design could also be humans´ in-build preference for exaggerated forms which are often found in iconic design. This is discussed in detail in the author´s Bachelorthesis.

4. ROBOT MOTION

The previous section discussed a way to give robots a certain look which could be beneficial for human-robot interaction because of its simplicity and distinctiveness. An advantage of iconic appearance is furthermore that movements might be highlighted. The robot possesses little features and if these features move it would be immediately salient. Making robot motion foregrounded in human-robot interaction research might be a good choice as motion is a strong trigger of ascribing anthropomorphic attributes to non-living things. Even simple geometrical forms can be perceived as lifelike if they move in a systematic way (Heider & Simmel, 1944).

Robot motion, to be successful in promoting human-robot interaction, has to be elaborated thoroughly because humans are highly sensitive to the motion of their interacting partner (Gee, Browne & Kawamura, 2005). Humans read subtle cues from their counterpart from which the counterpart´s next reaction can be predicted. This prediction could be based on prior knowledge of previous encounters with other humans. Robots unfortunately miss these tiny cues most of the time, so their behavior is unpredictable to humans (Gee et al., 2005) which could make the interaction less pleasant and natural. Additionally research showed that participants, when given the opportunity to predict a robot´s behavior, did like the interaction more (Akiwa, Suga, Ogata & Sugano, 2004). The reason why these cues are not yet embedded in robot behavior might be because of their complexity or simply, because it is still not fully known how these cues look like in humans.

In developing robot motion velocity of movements is an important aspect. The behavior itself and the speed with which it is exerted are two interdependent compounds.

Blow et al. (2006) conducted an experiment in which participants viewed videotapes of different smiling expressions of the iconic robot KASPAR. Manipulated variables were the speed by which KASPAR reached its smile and the amount of smiling. Speed was varied by using two different transitions from neutral expressions to smiling: A natural transition in which KASPAR reached a smile within 2 seconds and an abrupt transition wherein KASPAR immediately changed from neutral to smiling by cutting the video. The amount of smiling was changed by making the smile small, medium or large. Participants uniformly found KASPAR´s smiles with a natural transition more appealing than smiles which it reached immediately through abrupt transitions (Blow et al., 2006). The effects of amount of smile were inferior the effects of speed of transition. These results show that it is not exclusively the kind of behavior what influences a human´s reaction but also the velocity with which the behavior is performed.

Besides exhibiting behaviors on their own, robots must be able to perceive the behavior of humans and react to them in the right way. Without the ability of perceiving and understanding motion there could never develop any interaction. Additionally robot behavior, which is aimed at humans and in line with the humans´ own behaviors, acts as a strong motivator to engage in interaction with the robot (Michalowski, Sabanovic & Kozima, 2007). This finding resulted from an experiment with the robot Keepon in which he danced to music (Fig. 4). Keepon has a yellow-colored, snowman-like look and can turn his head and bounce with his body up and down to the rhythm of music.

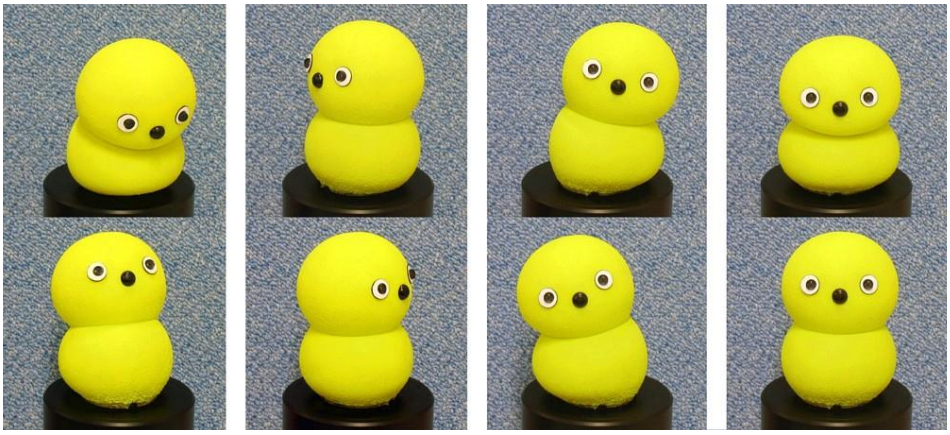

Fig. 4: Moving Keepon

Michalowski et al. (2007) were interested in the effect of rhythmic behaviors on interaction and they made the hypothesis that Keepon´s behaviors, either synchronic to background music or to the interacting partner, would have a positive influence on the quality of interaction. Interaction took place when children approached Keepon to dance with it. Results showed that more children approached Keepon when it already was moving in synchrony to the background music, so as already mentioned synchrony to the environment and perhaps also to the potential interaction partner, serves as a great motivator to actively start an interaction (Michalowski et al., 2007). Additional observations showed that children were strongly focusing on Keepon´s movements and tried to teach it new movements. If Keepon reacted to the childrens´ attempts through his visual recognition system, this resulted in expressions of happiness and satisfaction in the children (Michalowski et al., 2007). So at least children considered Keepon to be a lifelike creature. If synchronized behavior to the environment serves as a motivator to engage in interaction with a robot, the fact that children exhibited feelings of satisfaction when Keepon responded to them could also reveal synchronized behavior to the interacting partner as another motivating factor which keeps a human occupied with a robot. So the development of appropriate and well-timed robot behavior should be an important goal in human-robot interaction research.

5. THE EXPERIMENT

5.1 Hypotheses

Besides the question whether motion would make a humanoid appear more human-like, the experimenter is also interested in the influence of motion on interaction with the Nao and on use of anthropomorphic terms. Furthermore, it would be interesting to look at a possible relation between human-likeness and liking of the Nao. The following hypotheses are investigated:

H1*: A moving Nao will appear more human-like to the subjects than a still Nao.*

H2*: Subjects who saw the Nao moving will make more use of anthropomorphic terms towards the Nao than subjects who did not see the Nao moving.*

H3*: Subjects who saw the Nao moving will spend more time to inspect it. Furthermore, their inspection might be different from the inspection of control subjects.*

H4*: There will be a positive relation between human-likeness and liking of the Nao.*

5.2 Participants

In total 10 subjects were tested from which six were assigned to the control condition and four to the experimental condition. All subjects were psychology students at the University of Maastricht and their age ranged from 20 to 26 years with a mean age of 21.4 years. Nine subjects were female and one was male. Subjects were recruited through an advertisement on the webpage of Maastricht University (EleUM) and also by several paper advertisements which were placed on the notice boards at the faculty of psychology. All subjects completed the whole experimental session and except one they were rewarded with 0.5 experimental credits (“proefpersoon punten”).

5.3 Procedure and Material

At the beginning of the experiment all subjects were first asked to sign an informed consent form to confirm that their participation is voluntary and that they are free to stop with the experiment whenever they want. They were randomly assigned to a condition and according to the condition, the subjects received a short summary what they are going to do in the next half hour. Two conditions were used: One control condition and one experimental condition. In the control condition the Nao was switched off and kneeling on a table in a stable position. The subject is told that the experimenter is curious about his or her opinion about the Nao and the subject is encouraged to inspect the Nao in terms of lifting it up or moving its limbs. The duration of inspection is measured and during the inspection the experimenter observes the subject´s behavior and potential utterances towards the Nao. When the subject is not engaged any more in inspecting the Nao, he receives a questionnaire aimed to measure his opinion about the Nao in general and about his inspection of the Nao. In the experimental condition, the Nao is switched on and standing on the ground while the subject is entering the room. It is connected to the internet with an Ethernet cable and also its battery charger is plugged in to prevent losing power during the session. The subject is seated approximately one and a half meters away from the Nao and the Nao starts moving. The used movements were prepared in advance in Aldebaran´s software Choreographe. It walks one meter towards the subject and shows its hello sign, which consists of raising its right arm and waving. Then the Nao turns around 180 degrees and walks back the same distance. At the end it turns around 180 degrees so that it is standing in the same position as when it started moving. The motion sequence is chosen, because walking on two legs is a sort of motion withheld for humans so consequently might let appear the Nao more human-like. The waving part in between is also chosen to resemble a human gesture and also to make the subject feel addressed personally. When the Nao has finished his motion sequence it is switched off by the experimenter and placed on a table in a stable position. Then the experiment further proceeds as in condition one.

The questionnaires which participants have to fill in after interaction with the Nao start with the humanlikeness and machinelikeness scales borrowed from Powers and Kiesler (2006). Because the machinelikeness scale consists only from the item ‘machinelikeness’ it was also included in the humanlikeness scale and counted as a negative item. Then Monahan´s liking question (1998) was changed according to the subject´s different modalities with which he could interact with the Nao. Examples are the questions how much the subject liked touching the Nao and looking at it. The appealing question from Blow et al. (2006) was also embedded between the different liking questions. Questions from MacDorman et al. (2008) are used to measure the subject´s familiarity and possible fear of robots. At the end Reysen´s likeability scale (2006) is used to assess different emotions which the subject´s might have towards the Nao. The whole questionnaire can be found in the appendix.

The behavioral observation secretly done by the experimenter consists of counting the frequency of the following behaviors while the subject is inspecting the Nao: How many times does the subject move the limbs or head of the Nao and does the subject lift the Nao, speak to it or stroke it. There is also room left to note behaviors which are not yet incorporated in the checklist. Furthermore the experimenter notes whether the subject makes use of anthropomorphic terms if he speaks to the Nao. If he does, some examples can be noted. The checklist, which is during the experiment only visible to the experimenter, is also included in the appendix as the last page of the questionnaire.

5.4 Statistical Analysis

All analyses were carried out in SPSS 15 for Windows. First, a between-subjects One-way Analysis of Variance (ANOVA) was used to assess possible differences between the two conditions. Then a correlation table was constructed to look at possible relations between variables without splitting up subjects into conditions.

6. RESULTS

6.1 ANOVA

First, it was looked at the distribution of the variables to assure that the assumptions for using an ANOVA were fulfilled. The first assumption requires the variances between different levels of the independent variable (the two conditions) to be equal. To test this assumption a rule of thumb was used which states that the biggest variance should not be larger than twice the smallest variance. The assumption of equal variances was violated for almost every variable. However, violating this assumption is not dangerous if the group sizes of the different conditions are almost equal, which was the case in this experiment. The second assumption states that the distribution of each variable has to be normal for each level of the independent variable. This assumption was only violated in four of 56 possible cases, so no data transformations, which would result in normalizing a skewed distribution, were performed.

With alpha set at .05 there was no significant difference between the two groups concerning Powers´ and Kessler's humanlikeness scale in its whole. The same held for the Reysen Likeability scale. Therefore it was decided to carry out an ANOVA with all items from the two scales, to see whether there were individual items which were significant. Furthermore, all other variables from the questionnaires were included in the ANOVA. Again the results showed no overall difference between the two groups. The only significant difference between groups was found for the item "Familiarity with robots" [$F(1,8) = 5.52$; $p = .047$]. The main familiarity rating in the control condition was 2.3 points, in the experimental condition it was 1.3 points. As familiarity has to with someone´s prior knowledge it could not be a consequence of the experimental manipulation, so the difference between groups is likely to be accidental. Items which were just not significant were "machinelikeness" [$F(1,8) = 4.5$; $p = .07$] and "The Nao is similar to me" [$F(1,8) = 3.9$; $p = .08$]. The control group rated the Nao with a mean of 6.2 points on machinelikeness whereby the experimental group rated the Nao with 5.3 points. Subjects from the control condition rated the Nao as being more similar with themselves than subjects from the experimental condition (2 points as opposed to 1.3 points). All other items had a p-value above .10.

6.1.1 Looking at the Means

Despite the non-significance of most variables at least some tendencies of the subject´s answers could be observed (Fig. 5). However, there was no overall difference in the means of the observational variables (which parts of the Nao did the subject move during the interaction, did the subject talk to the Nao). Some parts of the Nao were moved more often in the control condition (the head) whereby other parts were moved more often in the experimental condition (moving the limbs, turning the Nao, lifting the Nao). There were two cases observed were a subject spoke directly to the Nao in an anthropomorphic way, but both cases occurred in the control condition. Utterances of the two subjects were “You should keep standing!” and “You are very sympathetic.”. In general, subjects in the control condition interacted longer with the Nao than subjects in the experimental condition.

Concerning the humanlikeness scale, subjects in the experimental condition rated the Nao higher on most items. For example, subjects in the experimental condition more often thought that the Nao had a mind and found that it moved in a human way. On the other hand, subjects in the experimental condition rated the Nao as less natural than subjects in the control condition did and there was no difference between the means of the groups in the Nao´s lifelikeness. Concerning the Reysen Likeability scale subjects in the experimental condition rated the Nao higher on the attributes “friendly”, “likeable” and “warm”. On the other hand, subjects in the control condition more strongly thought that the Nao was similar to them, that the Nao was approachable and that they would like to be friends with the Nao. However, differences in means for the latter item were very small (a difference of 0.17 points).

Subjects in the experimental condition liked touching the Nao and looking at it more than subjects from the control condition. There was no difference between means on the third liking item which concerns moving the Nao. Furthermore experimental subjects rated robots in general as being a smaller threat than control subjects did but there was no difference between groups in ratings about how threatening people are.

Means humanlikeness items

Condition	Natural	Humanlike	Lifelike	Machinelike	Has a mind	Moves human
Control	2.67	4.00	3.50	6.17	1.83	3.83
Experimental	2.50	3.50	3.50	5.25	2.25	4.00

Means Reysen Likeability items

Condition	Friendly	Likeable	Warm	Approachable	Similar to me	Friends with Nao
Control	4.50	5.00	3.17	4.50	2.00	3.16
Experimental	5.00	5.75	3.50	4.25	1.25	3.00

Means observational variables

Condition	Moving limbs	Moving head	Lift the Nao	Talk to the Nao	Stroke the Nao	Turn the Nao
Control	1.17	1.00	0.67	0.33	-	0.83
Experimental	1.25	0.75	0.75	-	-	1.25

Condition	Duration of interaction (sec.)	Antropomorphic terms
Control	85.67	0.33
Experimental	74.00	-

Fig. 5: Tables with means of different items

6.2 Correlations

To see whether there would be a positive relationship between experienced human-likeness and liking of the Nao, a correlation table was constructed. Subjects were no longer divided into groups as the influence of motion does not have to be considered in this analysis. Indeed there was a positive correlation between the overall score on the Powers´ and Kiesler´s humanlikeness scale and the overall score on the Reysen Likeability scale (Pearson´s $r = .76$; $p = .01$). There was also a positive correlation between the Humanlikeness scale and the amount of liking the inspection of the Nao (in terms of liking the look of the Nao with $r = .73$, $p = .02$ and liking to move the Nao with $r = .84$, $p = .003$). The positive relation between human-likeness and liking to touch the Nao during inspection was just not significant ($r = .60$, $p = .07$).

Furthermore a significant positive correlation was observed between familiarity with robots in general and the use of anthropomorphic terms towards the Nao ($r = .66$, $p = .04$). There was no significant correlation found between the duration of interaction and liking of the Nao and also no correlation between human-likeness of the Nao and duration of inspection.

6.3 Other observations

In general the Nao was immediately approached with positive affect and interest. More than half of the subjects uniformly said that the Nao was “cute”. They also asked many questions about the Nao, for example where it came from and what its capabilities were. At first many subjects were reluctant to inspect the Nao and feared to damage it but after the experimenter gave an example how the Nao could be moved they seemed to enjoy the inspection. One subject also expressed the opinion that she believed in the possibility of social relationships with robots when these robots are more elaborated.

There were also two subjects which did not have such a positive view of the Nao or robots in general. Subject 8 expressed that she was not interested in robots at all and also never has been as a child. Furthermore she told the experimenter that she did not want to have robots in her personal life or at home. However, subject 8 did not exhibit fear to inspect the Nao and she admitted that for a robot the Nao looked nice. Subject 6 took part in the experimental condition and when she entered the room the Nao was already switched on and its LEDs were glowing. Immediately when she saw the Nao she got very frightened and uttered something like “Oh my god, this is it?”. When she was told to take a seat and watch the Nao moving, subject 6 was afraid and asked whether the Nao could harm her. The Nao´s motion sequence was then explained to her in detail and the experiment could proceed. At the beginning of the inspection, she also was afraid of breaking the Nao.

7. DISCUSSION

First of all, there was no important significant difference at all between the two experimental groups. Only the aspect of a subject´s familiarity with robots differed significantly between the groups. But as familiarity is assumed to involve prior experiences the difference seems to be independent from the manipulation and rather accidental. So it might be possible that the manipulation, seeing the moving Nao, did not have the desired impact on the subjects. It might be that the Nao´s motion sequence was too short or the Nao´s behavior not natural enough, resulting in a lack of influence on the subjects who watched the moving Nao. During further reading it should be kept in mind that most of the below mentioned effects derive from a comparison of the means without considering significance of the effects.

In general, only a few hypotheses were confirmed in the experiment. Hypothesis 1 states that the moving Nao should be perceived as more human-like by the subjects. If one could equate high human-likeness with less machine-likeness than the hypothesis might be confirmed. Subjects from the experimental condition rated the Nao as less machine-like than subjects from the control condition. So it is assumed that the Nao´s motion took away part of its mechanical appearance. This finding can be considered as most important in the experiment as the main aim was to show that less human-appearing robots can be perceived as human-like through their motion. Unfortunately, the effect of motion on machine-likeness was just not significant, but anyway this finding shows that the data went into the desired direction. A finding which might weaken a confirmation of hypothesis 1 might be that at the same time subjects from the experimental condition rated the Nao as moving more in a human way and as being less-natural than control subjects. Perhaps moving in a human way was caused solely by the fact that the Nao walked on two legs but for the rest its movements looked artificial. This possible artificialness might also be a reason that the experimental manipulation did not succeed as intended.

Hypothesis 2 states that seeing a moving Nao should increase the use of anthropomorphic attributions towards it. This hypothesis was negatively confirmed because only subjects from the control condition made anthropomorphic utterances about or towards the Nao. The only aspect which in this experiment seems to have an influence on anthropomorphic attributions was familiarity. Subjects who considered themselves as being familiar with robots spoke out more anthropomorphic utterances. Maybe these subjects already have prior knowledge about the manifold capabilities of robots and they consider robots in general as lifelike beings.

Hypothesis 3 assumes that subjects who saw the Nao moving should inspect it longer and in a different way than control subjects. The first aspect is not confirmed: Subjects from the control condition spend more time on inspecting the Nao than subjects from the experimental condition. Maybe experimental subjects knew some of the Nao´s movements from watching the motion sequence and therefore they did not have to try these manually during the inspection. When the control subjects had to inspect the Nao, they saw it for the first time and maybe wanted to get to know more about it by spending more time on inspection. There was also a qualitative difference in the subjects´ behaviors during the inspection, namely experimental subjects moved the Nao´s limbs more often during the inspection than control subjects did. Perhaps watching the Nao walk and wave increased their interest in movements of the arms and legs. An additional finding related to the third hypothesis was that experimental subjects liked the inspection of the Nao slightly more than control subjects. As said before, maybe the motion sequence increased the subjects´ interest in the Nao. Another possible reason for their heightened interest might be that experimental subjects felt directly addressed by the waving movement of the Nao. Furthermore, there was neither a relation between duration of inspection and liking, nor a relation between duration and human-likeness.

Hypothesis 4 supposes that there might be a positive relation between human-likeness and liking of the Nao. This hypothesis was confirmed, even with significance of the outcome. The fact that humans like other humans is likely to be an evolutionary preference, but this finding supports the notion that also non-human beings are liked more as they become more human-like. There was also a relation between the amount of human-likeness and liking of the inspection of the Nao. Liking the Nao and liking to inspect the Nao seem to be two interdependent aspects, so the latter relation had to follow logically from the first one.

Furthermore there had been two interesting additional findings. First, control subjects rated the Nao as being more similar to them than experimental subjects. Maybe motion simply was not human-like enough, so seeing the walking Nao might have caused a certain detachment towards the Nao in the experimental subjects which was not the case in control subjects. A factor which could support identification with the Nao in control subjects might be its iconic appearance, which is so universal that a subject might project herself on the Nao. A second interesting finding was that experimental subjects rated robots in general as being a smaller threat than control subjects. Maybe subjects in the experimental condition generalized the Nao´s simple movements to all other robots and therefore robots did not appear frightening to them.

7.1 Limitations

The non-significance of almost every outcome indicates that the experiment shows some major limitations. The most obvious reason might be a very low power of the analysis caused by the small number of subjects. To have sufficient power every condition should consist of at least fifteen subjects, the more the better. In this experiment it was not possible to recruit such a large number of subjects, mainly because of the short testing period. Furthermore the duration of interaction with the Nao presumably was no good indicator of aspects as human-likeness or liking of the robot. Also there might be a problem with including the machinelikeness item in Powers´ and Kiesler´s Humanlikeness scale. The idea behind this was to consider machinelikeness as the opposite to humanlikeness, but this relation was not seen by many subjects. There were several cases where the Nao was rated high or low on human-likeness and the same on machine-likeness. Especially in the case of a low evaluation, subjects might have seen the Nao as not human-like because of its looks and motion, but also considered the Nao not to be machine-like as it possesses a face and a body. As the machinelikeness item might cause ambiguities, it should not be included in the humanlikeness scale.

8. CONCLUSION

This paper tries to assess the usefulness of humanoid robots for research on human-robot interaction. Humanoid robots have the advantage of eliciting no negative feelings as unease or fear in humans because they are immediately identified as robots (Mori, 1970). This immediate identification prevents the human from having too high expectations about the robot´s capabilities which would not be fulfilled. Furthermore humanoids possess a reduced iconic appearance which provides them with a unique look (Dautenhahn, 2002). It also enables the human to identify himself with the humanoid, because iconic appearance is universal thus can represent a great number of persons (Blow et al., 2006). Because humanoids have a body and limbs they can exhibit a great range of behaviors, a capacity which might be very important in human-robot interaction as motion is a great perpetrator of anthropomorphic attributions. The motion capacities of humanoids should be used to make robot motion more natural and human-like during interaction with humans. At the same time, humans would not exhibit negative feelings towards humanoids as their look is less human-like.

The experiment tried to set a step towards the usage of humanoids for human-robot interaction research by assessing the effects of the robot Nao on human test subjects. The experimenter was interested in the influence of motion on the amount of human-likeness the subjects ascribed to the Nao and in the extend to which the subjects liked the Nao. An effect of motion was not found in the experiment, probably because of the small group sizes or too weak experimental manipulation, but it was found that subjects who rated the Nao as human-like also liked the Nao. The latter finding supports an already existing assumption for robot design: Human-likeness of robots supports human-robot interaction. Whether human-likeness concerns the robot´s appearance or its motion unfortunately could not be specified during the experiment. Future research should focus on the hypothesis that one can achieve human-likeness in a robot solely through its motion by testing more subjects and using a more natural motion sequence of the robot. If this hypothesis would be confirmed the usage of humanoid robots for research will be justified with all its advantages. Achieving good human-robot interaction is a complex aim, but it does not need complex methods.

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10. APPENDIX

Participant number*:* __________

Gender: m ___
f ___

Please indicate to what extend the Nao has the following qualities:

	not at all					*very much*	
natural	1	2	3	4	5	6	7
human-like	1	2	3	4	5	6	7
life-like	1	2	3	4	5	6	7
machine-like	1	2	3	4	5	6	7
has a mind	1	2	3	4	5	6	7
moves like a human	1	2	3	4	5	6	7

How much did you like touching the Nao?

not at all *very much*

1 2 3 4 5 6 7

How appealing does the Nao look?

not at all *very much*

1 2 3 4 5 6 7

How much did you enjoy moving the Nao?

not at all *very much*

1 2 3 4 5 6 7

Please rate how threatening you feel robots are:

not at all *very much*

1 2 3 4 5 6 7

Please rate how threatening you feel people are:

not at all *very much*

1 2 3 4 5 6 7

How familiar are you with robots?

not at all *very much*

1 2 3 4 5 6 7

How interested are you in robots?

not at all *very much*

1 2 3 4 5 6 7

	not at all						*very much*
This Nao is friendly.	1	2	3	4	5	6	7
This Nao is likeable.	1	2	3	4	5	6	7
This Nao is warm.	1	2	3	4	5	6	7
This Nao is approachable.	1	2	3	4	5	6	7
This Nao is similar to me.	1	2	3	4	5	6	7
I would like to be friends with this Nao.	1	2	3	4	5	6	7

Thank you for participating!!

Experimenter only!

Duration of inspection:

___________ minutes

Behaviour during inspection:

Moving limbs of the Nao: ____ x

Moving the head: ____ x

Lift the Nao: ____ x

Talk directly to the Nao: ____ x

Stroke the Nao: ____ x

Other:

____

____

Anthropomorphic terms:

____ x

Examples:

____

____

____

____

____