

Effects of Visual Appearance on the Attribution of Applications in Social Robotics

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Abstract — This paper investigates the influence of visual appearance of social robots on judgments about their potential applications. 183 participants rated the appropriateness of thirteen categories of applications for twelve social robots in an online study. The ratings were based on videos displaying the appearance of the robot combined with basic information about the robots' general functions. The results confirmed the hypothesis that the visual appearance of robots is a significant predictor for the estimation of applications in the eye of the beholder. Furthermore, the ratings showed an attractiveness bias: robots being judged as more attractive by the users also received more positive evaluations (i.e., "liking").

I. INTRODUCTION

The general objective of social robotics research is to design robots that engage in social scenarios which are compelling and familiar to human beings. Thus, robots have to provide a social communicative functionality that is natural and intuitive. Today, simple social robots are sold as toys. More complicated systems are usually used for research – but these are far from being commercial products.

Research on applications offers interesting scientific challenges: First, many functional as well as socially relevant aspects are only observed when realistic applications are faced. Second, a thorough evaluation of the robot performance that includes social aspects of human-robot interaction gains significance from well defined application scenarios. However, we have observed that in experimental settings not only the robot but also the setting of the application need to be explained to users in order for them to engage in a meaningful task-oriented interaction. Especially for naïve users, robots need to be self-explaining. This can be supported by matching visual appearance and functionality with the robot's tasks.

The idea of robots as artificial beings is hundreds of years old: The original meaning of *automaton* implies autonomous beings having the ability to move on their own. Vausanson's flute and tabor player [1] and Wolfgang von Kempelen's famous chess player [2], the Turk, designed in the mid-17th century, are early automatons, but they are mainly early encounters between lifelike forms and mechanical machines. These machines invoked people's projections and expectations due to the lifelike behavior which is displayed by the visual appearance.

Altogether, an implicit knowledge exist of what tasks people expect a robot to do and what tasks people expect a robot explicitly not to do due its visual appearance. In the present study we address the lack of systematic research on the relations between the visual appearance of social robots and applications. Therefore, we asked our potential users what applications they expected the twelve social robots could have. This investigation focuses on potential applications for the twelve robots Barthoc Jr., iCat, Aibo, BIRON, KeepOn, Kismet, Leonardo, Robovie, Repliee Q2, Asimo, Paro, and Pearl.

Section II gives a brief overview of the related work. Section III introduces the twelve robots and explains the method of the study. In Section IV we discuss the results and finally, Section V concludes this paper.

II. RELATED WORK

This section address related work regarding definitions of social robots (Section 2.1), applications for social robots (Section 2.2), and visual appearance of social robots (Section 2.3). Additionally, Section 2.4 gives a short introduction into the attributions due to attractiveness.

2.1 Social Robots

Initially, the idea of creating social robots was inspired by biology. Social robots were used to study swarms or the behavior of insects [3]. However, current approaches of social robotics treat the interaction between humans and robots. The term social in this case represents the fact that there are two or more entities within the same physical context [4]. A social robot is able to communicate with human beings, understands and even relates to humans in a personal way. It should be able to understand humans and itself in social terms [5]. Therefore, social robots are explicitly developed for the interaction between humans and robots to support a human-like interaction because the most intuitive and appropriate way to instruct robots is to interact as naturally as humans do in their everyday life.

2.2 Applications for Social Robots

The fact that there are only a few commercial applications for social robots today leads to the conclusion that it is challenging to develop useful applications for such robots. Today's successful application scenarios for robots with the need of social capabilities are almost restricted to research scenarios and toys. But in principal there is the motivation to find meaningful applications for robots. For instance, based on an interdisciplinary workshop with the goal to conceive

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potential applications, Ljungblad [6] reported on three selected scenarios: self-organizing robot plants, robots as travel companions, and amusement park guide robots.

To establish further successful applications the value of the robots has to meet the needs of the users – the robot has to find its place in human life by adding value to it in terms of short- or long-term usage [7]. But which jobs should robots do in the public opinion to add value to the everyday life? Takayama et al. [8] found that people favor robots for jobs that require memorization, keen perceptual skills, and service-orientation. Furthermore, they showed that people would feel more positive toward robots if they performed tasks with people rather than to replace them.

In a survey of socially interactive robotics, Fong et al. [3] describe several application fields. Social robots can be used as test subjects for research on communication and human development theory as well as short-term and long-term service assistants in public and private life. They can also be used as toys and entertainment devices, for therapy (e.g. of autism), for research on anthropomorphism, and in the field of education.

According to Christensen [9], there are three principal commercial application categories in the field of domestic tasks: entertainment, everyday tasks, and assistance to elderly and handicapped people. The performance metric of entertainment applications is forgiving, i.e. the robot is not really required to perform specific tasks. As long as the robot performs interesting things in terms of interaction generally the users will in general be satisfied. The performance metric of everyday home tasks for domestic robots is well defined while the individual environment where they will have to fulfill these tasks cannot be anticipated. Finally, assistance applications for elderly and handicapped people are mainly motivated by the demographic profiles of occidental societies. The performance metric of these applications is a high degree of flexibility and an easy instruction how to interact with the robots.

In [10, 11, 12] we introduced first studies in which potential users proposed applications for social robots. In this paper we further promote this idea (see Section 3.2).

2.3 Visual Appearance of Social Robots

The visual appearance of robots substantially influences the assumptions humans have about specific applications [10, 11] and functionalities [13]. Four general categories of visual appearance in social robotics were differentiated by Fong et al. [3]: functional, caricatured, zoomorphic, and anthropomorphic design.

Functional robots are explicitly designed to communicate their ultimate functions and often have a technical appearance. Zoomorphic robots are intended to look like their animal counterparts to support the idea that an observer expects the robot to behave like the respective animal. In some cases this might be helpful to point out the functional limitations of a robot. For example, a dog is partly able to understand aspects of human language but the communication skills are limited. This mirrors the quality of speech recognition software.

Robots with a caricatured appearance, however, are mainly designed to focus on very specific attributes like mouth or eyes. They do not elicit any familiar expectations. Especially as machines enter home and workplace, our interaction with them becomes more sophisticated. Within this context, it is assumed that a human-like looking and behaving robot is easiest to use as interface to humans because humans are highly skilled interacting with other humans. Consequently, an anthropomorphic robot indicates human qualities with the supposition that the more anthropomorphic a robot looks like the more the user will expect the robot to behave like a human being [14]. DiSalvo and colleagues [15] speculate that the degree to which people anthropomorphize depends on the quantity of human attributes. Therefore, the more human attributes a robot displays, the more it is rated as human-like and accordingly, more people attribute human qualities like a typical human behavior to the robot [16, 17].

It is well-known that people have visual preferences due to the appearance of other humans and objects. That is one reason why some robots are preferred to others. Attractiveness appears to have an influence on the expected performance of humans and objects as will be shown in the following.

2.4 Attractiveness Bias

In fairy tales, the heroines and heroes are attractive and the villains are ugly. For example, in the wellknown novella ‘Strange Case of Dr. Jekyll and Mr. Hyde’ [18] Dr. Jekyll is “A large, well-made, smooth-faced man [...]” while the misanthropic Mr. Hyde is unattractive: “Pale and dwarfish, he gave an impression of deformity without any nameable malformation, he had a displeasing smile”. Attractiveness has effects on the attribution of good traits [19].

Humans who are more attractive are evaluated as being warmer, kinder, stronger, more sensitive, interesting, poised, modest, sociable, and outgoing [20]. To sum up, numerous findings in psychology show that humans believe that attractive people possess positive qualities that unattractive people lack [e.g. 20, 21, 22, 23]. Even babies at the age of 12 months prefer to play with attractive instead of unattractive puppets [24]. Norman [25] claims that this attractiveness bias is also applicable to objects.

On the contrary, extremely unattractive objects elicit negative human reactions. The best known hypothesis on negative aesthetical effects within social robotics is the wellknown Uncanny Valley hypothesis [26], which represents how an object can be perceived as having enough human-like characteristics to evoke a constrained degree of empathy through one’s ability to rationalize its actions and appearance. When the movements and the appearance are almost human-like but not entirely, there are too many expectations of the capabilities and the result is a negative reaction from the observer. In the end, the object becomes so human-like that it is effectively treated as a human being when it has, to a sufficient degree, established a balance between anticipated and actual function and form [14].

This is consistent with the experiments realized by Seyama and Nagayama [27]. They proved that subjects feel

unpleasant when they perceive abnormalities within a human-like face. In daily life people rarely confuse artificial faces with real human faces – people do not ask a mannequin in a store for directions to a train station. This suggests that the human visual system has a specific sensitivity to the degree of human-likeness. Therefore, Seyama and Nagayama argue that the visual system is highly sensitive to abnormalities. In their experiments it has further been shown that a high degree of abnormality elicits unpleasantness within the tested subjects only if entities exhibit a high degree of realism. Improving the degree of realism of robots without removing potentially abnormal features may lead to an exaggeration of the observers' unpleasant impressions of the artificial faces.

What can be derived from these analyses of applications for social robots is that the place that social robots take in everyday surroundings depends mainly on their application scenario, functionality and appearance.

III. METHOD

The present study is an internet survey in which participants were asked to rate how well different kinds of applications matched with different robots depending on the visual appearance of the robots. Before the method of the study will be explained in detail a brief overview of the presented robots is given.

3.1 Robots

Altogether twelve different robots were presented to the participants (see Figure 1). Four robots that were already used in our preliminary study [10, 11, 12]. Barthoc Jr. (a) is an anthropomorphic robot developed at Bielefeld University, mainly used for research on communication and emotions in relation to human-human communication [28]. The Philips iCat (b) research platform is a plug&play desktop robot which originally served as an interface robot to an intelligent home scenario where people can naturally interact with the robot [29]. The AIBO Robot ERS-7 (c) is a commercial dog-like robot developed by Sony [30]. The robot platform BIRON (d) is developed at Bielefeld University and serves as a companion in a home tour scenario to study human-robot interaction [31].

Additionally, eight more robots were used to provide a broader spectrum. Keepon (e) is a small creature-like robot designed to interact with children by directing attention and expressing emotion with its body [32]. Kismet (f) and Leonardo (g) are two research robots with a rather caricatured shaped which were developed at the Massachusetts Institute of Technology. Especially Kismet has the ability to show a variety of facial expressions [5, 33]. Robovie (h) with its technical shape and the highly anthropomorphic Repliee Q2 (i) are two interactive humanoid robots developed by Ishiguro and colleagues [34, 35] for human communication research. ASIMO (j) is a well-known humanoid research robot developed by Honda [36]. Paro (k) is commercially used as a therapeutic robot. It looks like a seal and it was developed to interact with human beings and to make them

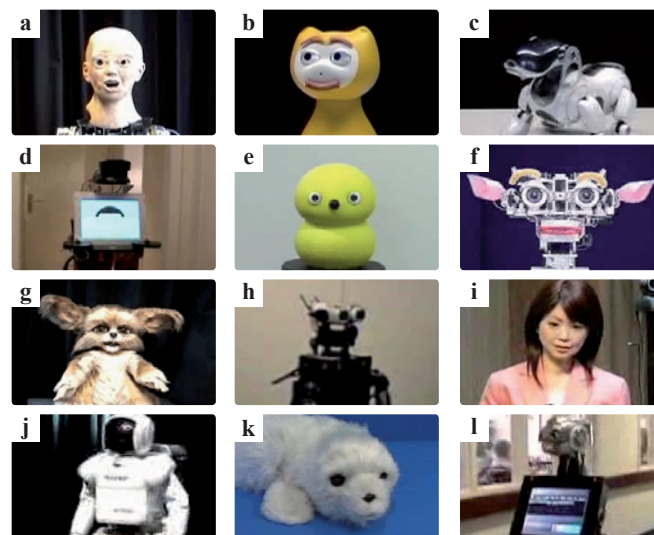


Figure 1. The twelve robots in the different videos presented to the participants: (a) Barthoc, (b) iCat, (c) AIBO, (d) BIRON, (e) Keepon, (f) Kismet, (g) Leonardo, (h) Robovie, (i) Repliee Q2, (j) ASIMO, (k) Paro, and (l) Pearl

feel emotionally attached [37]. Pearl (l) is a mobile robotic assistant with a technical appearance developed at Carnegie Mellon University for interaction with elderly people [38]. In summary, all the presented robots were developed for research on various aspects of human-robot interaction and all the robots were used in the context of social robotics.

3.2 Study

In a first preliminary study [10, 11, 12], the participants were asked to conceive applications for the robots BIRON, iCat, Barthoc, and AIBO. The following thirteen application categories based on a (manual) content analysis of participants' results were derived:

1. *Security Robots* are used for surveillance, military tasks, exploration, tasks that are dangerous for humans like minesweeping, and for protection.
2. *Research Robots* are developed to learn about robotics and human nature or human-robot interaction, respectively. They serve to improve the robots themselves.
3. *Healthcare Robots* are used for therapy (e.g. autism therapy) or as a support for sick or old people.
4. *Personal Assistant Robots* serve as butlers, organizers or interfaces to technology. Moreover, this category includes robots used for cleaning and other household tasks.
5. *Toy Robots* are robots children or adults can play with.
6. *Business Robots* are receptionists, used for representation, or as sales robots.
7. *Pet Robots* are robots that might replace a pet.
8. *Entertainment Robots* have the capabilities to entertain people in various ways.
9. *Teaching Robots* are able to teach certain subjects or abilities to human beings.
10. *Transport Robots* are developed to conduct fetch & carry tasks in various situations.

11. *Companionship Robots* keep company especially in cases when someone feels or actually is lonely.
12. *Caregiver Robots* are developed for old/sick people or for children. They might look after somebody when nobody else is around.
13. *Public Assistant Robots* are used as guides (e.g., museum tour guide), as information terminals, or translators in public scenarios.

The robots of the first study were suited differently for these applications due to their form and function. In [11] four dimensions to divide between the applications were introduced: public vs. private [12]; intensity of interaction; complexity of interaction model; functional vs. human-like appearance.

In the present study, the fourth dimension from the first study was investigated with twelve robots. Special attention was paid to the visual appearance when selecting the robots (see Section 3.1). Comparably to the first exploratory study [10] an internet survey was conducted for the same reasons: addressing naïve people with different backgrounds, minimizing the time needed to conduct the study, and minimizing context and technical problems that could occur in real interactions with the robot. People were asked to make a judgment based on the appearance of the robot in a video and a short description of its functionality.

The study was published in English on several internet forums and websites all over the world. These were not associated with the robotics community.

The questionnaire consisted of three parts. The first part included questions about age, gender, education, nationality, and profession. Moreover, participants were asked to rate their computer skills and to chose the robots they knew out of a list of 16. In the following part of the questionnaire, the participants were shown eight out of the twelve robots, which were chosen randomly to shorten the time participants had to spend on the online survey.

The videos of each robot were about three seconds long and were not presented with much context information. In the videos, the robots mainly conducted some short movements (e.g. Aibo: getting up on its feet and turning; Keepon: first looking to one side and then turning to the viewer; Paro: opening and closing its eyes). To avoid priming of the viewers, any concrete tasks the robot could perform in a certain environment were avoided to be shown. In contrast to simple pictures, the videos give the viewer a better sense of the embodiment of the robot. The videos were replayed as long as the subjects stayed on the given site of the questionnaire. There was no sound because voices and background noise might have a significant effect on the perception of the robots.

For each robot, the participants were asked to rate the following questions regarding applications, visual appearance, and sympathy on a 5-point scale (1=not at all; 5=very much):

(a) Questions regarding applications

How suitable are the 13 applications for each of the twelve robots (see Section 3.1)?

(b) Questions regarding visual appearance

How human-like does the robot look?

How functional / technical does the robot look?

How similar to an animal does the robot look?

(c) Questions regarding sympathy

How much could you imagine using the robot?

How likeable is the robot to you?

How enjoyable is the robot to you?

How much would you like to own this robot?

How attractive is the robot to you?

The different application categories were explained in a short text which appeared when the mouse pointed on a certain category. At the beginning of the study the participants were explicitly told that they had this option and it was also written on every page.

In the last part of the questionnaire the participants had the chance to write down comments and send a link to their friends.

IV. RESULTS AND DISCUSSION

This section presents the results of the study, including results regarding the rated applications (Section 4.1), visual appearance (Section 4.2), and sympathy ratings (Section 4.3).

Altogether, 183 individuals (41% female, 59% male) participated in the study. Their age ranged between 13 and 70 years (mean 27.84). The majority of the subjects were German (116), followed by US American (19), British (9), and the rest (38) from all over the world. Due to the different group sizes an intercultural differentiation was not possible. Furthermore, the participants were highly educated (33% high school/A-level, 56% university degree, 7% doctoral degree), 78% of the participants used a computer at home as well as at work (17% only at home), and 63% of the subjects thought they had advanced computer skills (13% beginners, 24% experts).

In total, all participants knew 823 robots (including ‘others’) without any systematic differences. On average, each participant knew 4.5 robots. Only eight subjects (4%) knew between 10 and 15 robots. Therefore it is assumed that the participants were no experts in the field of social robotics, although being in general very interested in and positive about robotics. The most familiar robots were: robots for mars exploration (121 participants), R2D2 from Star Wars (94), soccer robots (92), Lego Mindstorms (88), Honda Asimo (85), vacuum cleaning robots (84), Sony Aibo (67), service robots in general (65), and Kismet (32).

4.1 Results regarding Applications

The participants rated eight robots which were assigned to them randomly. The twelve robots were rated between 80 and 132 times (see Table 1).

The robots in the present study were in general most appropriate for applications such as entertainment (mean 3.4), toy (mean 3.3) and research (mean 3.1). This corresponds

Table 1. Mean ratings regarding applications, appearance, and sympathy rated from 1 (not at all) to 5 (very much)

	Robots	Barthoc Jr.	iCat	Aibo	BIRON	KeepOn	Kismet	Leonardo	Robovie	Repliee Q2	Asimo	Paro	Pearl	mean
How suitable are the following applications for this robot?	(1) Security	2.22	1.69	2.53	3.07	1.87	1.99	1.53	3.28	2.33	3.38	1.48	3.14	2.36
	(2) Research	3.43	2.54	3.04	3.45	2.23	3.38	2.53	3.57	3.48	3.90	2.33	3.61	3.11
	(3) Health Care	2.14	2.24	2.14	2.72	1.91	2.25	2.13	2.84	2.96	3.05	2.62	2.72	2.48
	(4) Assistant or Interface	3.00	2.40	2.32	3.54	2.03	2.79	2.08	3.53	3.34	3.63	1.69	3.76	2.82
	(5) Toy	2.19	4.19	4.47	2.02	4.36	3.17	4.38	2.74	2.32	2.70	4.72	1.95	3.31
	(6) Business or Representation	2.89	2.16	1.91	3.17	1.64	2.49	1.97	2.96	4.02	3.25	1.59	3.42	2.61
	(7) Pet	1.51	3.67	4.35	1.46	3.75	2.57	4.11	1.93	1.53	1.86	4.51	1.44	2.77
	(8) Entertainment	2.79	3.78	4.20	2.54	3.69	3.46	3.98	2.98	3.33	3.09	3.93	2.83	3.41
	(9) Teacher	3.03	2.41	1.83	2.87	1.76	2.84	2.26	2.76	3.63	3.04	1.72	3.00	2.58
	(10) Transport	1.49	1.23	1.70	2.29	1.13	1.27	1.11	2.83	1.40	2.95	1.23	2.92	1.77
	(11) Companionship	2.41	2.95	3.63	1.98	2.79	2.83	3.43	2.61	3.14	2.84	3.76	2.39	2.92
	(12) Caregiver	2.21	2.01	2.20	2.11	1.78	2.07	2.11	2.53	2.65	2.82	2.18	2.48	2.26
	(13) Public Assistant	2.92	2.26	1.96	3.52	1.85	2.60	2.14	3.36	3.84	3.33	1.44	3.77	2.73
Additional questions	Human-Likeness?	3.12	1.68	1.37	1.44	1.42	2.48	1.57	2.36	4.65	3.75	1.26	2.30	2.29
	Technical/Functional Appearance?	3.72	2.43	3.54	3.62	2.11	3.72	2.11	3.90	2.70	3.96	2.00	3.81	3.11
	Animal-Likeness?	1.18	3.17	4.05	1.13	3.27	2.35	4.11	1.44	1.24	1.27	4.58	1.35	2.46
	Imaging using the robot?	2.21	2.31	2.90	2.70	2.54	2.49	2.50	2.75	2.64	2.95	2.65	2.99	2.64
	How likable is the robot?	2.12	2.67	3.26	2.32	3.03	2.61	2.99	2.84	3.02	3.28	3.41	2.82	2.88
	How enjoyable is the robot?	2.27	2.59	3.20	2.35	2.92	2.67	2.90	2.77	2.85	3.08	3.17	2.55	2.79
	Like to own this robot?	2.01	2.23	2.76	2.16	2.48	2.20	2.34	2.52	2.36	2.75	2.63	2.50	2.42
	How attractive is this robot?	1.90	2.37	3.05	2.06	2.73	2.21	2.68	2.51	3.02	3.02	3.21	2.46	2.62
	total number of ratings	90	114	124	127	132	124	123	118	132	127	112	80	1403

with available application scenarios. Hence it was easier for the participants to think of applications for the robots that are already ubiquitous. In contrast, the robots were less suitable for currently unavailable application scenarios like caregiver (2.3). This result may be enhanced by the fact that people prefer to cooperate with robots rather than having them perform tasks on their own responsibility [8]. The twelve robots were least suitable for transport (1.7), because all robots but Asimo do not appear to have the ability to carry heavy things around like industrial robots do. Please keep in mind that also the analyses for the application groups presented in the following are based on the robots shown and might change for robots with different appearances.

(1) *Security*. Asimo (3.38), Robovie (3.28), Pearl (3.14), and BIRON (3.07) were best suited for security applications. This may be due to the fact that they are mobile robots and ‘taller’ than the other robots. One person explicitly commented regarding this application field that ‘the robots are not big and strong enough for security’.

(2) *Research*. The results for social robots as research applications were high in general (3.11). Moreover, research as such does not require reliable robots used in everyday situations and, thus, research robots do not pose a threat. Higher ratings in research correlate with a technical/functional appearance of the robots (bivariate correlation of .398**). Asimo (3.90), Pearl (3.61), Robovie (3.57) BIRON (3.45), Barthoc Jr. (3.43), and Kismet (3.38) received the highest ratings as research objects while Paro (2.33) and Leonardo (2.53) received the lowest.

(3) *Health Care*. The results in the field of health care applications were generally low (2.48). Regarding health care the humanoid robot Asimo (3.05) and the anthropomorphic robot Repliee Q2 (2.96) were most suitable. This is consistent with the matching hypothesis [39] which claims that the visual appearance and social behavior of a robot should match the seriousness of the task and situation. Therefore, in socially intensive situations like health care, humanoid and anthropomorphic robots will probably be preferred.

(4) *Assistant or Interface*. Pearl (3.76) and Asimo (3.63) received high ratings as assistance robots or robots as interface to help people using their appliances, but also BIRON (3.54) and Robovie (3.53) were judged as assistant robots. All these robots are mobile and mobility seems to be one quality that people expect from assisting robots.

(5) *Toy*. On the one hand, Aibo (4.47), iCat (4.19), Paro (4.72), Leonardo (4.38), and Keepon (4.36) received very high ratings in the category of toy applications due to their animal-like appearance (bivariate correlation of .646**), because toys for kids very often have animal shapes and/or basic colors. On the other hand the robots with a human-like shape like Pearl, Repliee Q2, and Barthoc were not expected to serve as toys (bivariate correlation of -.264**). Therefore, for the robots shown, animal-likeness is one major quality of toy applications.

(6) *Business or Representation*. Repliee Q2 (4.02) and Pearl (3.42) were rated to be most appropriate for the field of business applications while Paro (1.59), Aibo (1.91) and Leonardo (1.97) were less suitable because they were seen

as toys which are contrary to the idea of serious business tasks. The conclusion is that animal-like robots were not seen as business robots or representational robots for companies (bivariate correlation of $-.412^{**}$).

(7) *Pet*. The results show that obviously Paro (4.51), Aibo (4.35), Leonardo (4.11), and iCat (3.67) seemed best suited as pets because they look most animal-like (bivariate correlation of $.771^{**}$). Of course, human-likeness (bivariate correlation of $-.339^{**}$) and technical/functional design (bivariate correlation of $-.282^{**}$) are not qualities a pet robot should have.

(8) *Entertainment*. The same is true for entertainment - the participants believed that animal-like robots are able to entertain people (bivariate correlation of $.427^{**}$). Animals also seem to be prototypical companions and therefore Aibo, Paro, and Leonardo were again highly rated for companionship applications.

(9) *Teacher*. Repliee Q2 (3.63) was most suitable as teacher, because it is the most human-like robot. Teaching correlates with human-likeness (bivariate correlation of $.445^{**}$), but not with animal-likeness (bivariate correlation of $-.301^{**}$).

(10) *Transport*. Applications regarding transport were judged low in general (mean 1.77) probably because most of the displayed robots do not have arms to grab an object and they cannot move. One participant commented: "There isn't a robot with the ability to grasp objects in the list". Hence only the ratings of Asimo (2.95) and Pearl (2.92) were higher than average because these robots are in principal able to serve in transportation tasks.

(11) *Companionship*. Paro (3.76), Aibo (3.63), and Leonardo (3.43) were rated most suitable as companionship robots. The participants rated the robots with an animal-like appearance higher in companion applications (bivariate correlation of $.383^{**}$). Actually as Banks et al. [40] found, loneliness is a common problem frequently encountered among the elderly in long-term care facilities, but elderly who live with a pet are less lonely than those who do not. Banks et al. concluded that also the existence of a robotic pet like Aibo reduces loneliness. Their findings are consistent with our results.

(12) *Caregiver*. The twelve robots were generally rated low (2.26) as caregiver. This is also consistent with the matching hypothesis [39] and the findings of Takayama et al. [8]: the situation of caregiving is highly social and the robots receive responsibility to observe people. The robots Asimo (2.82) as well as Repliee Q2 (2.65) received higher scores than the others.

(13) *Public Assistant*. Repliee Q2 (3.84), Pearl (3.77), and BIRON (3.52) were rated to be most suitable for applications in which the robots have to serve as a public assistants, i.e., to guide people in public situations. This application field correlated with the human-likeness (bivariate correlation of $.433^{**}$) and technical/functional appearance (bivariate correlation of $.306^{**}$) of robots, but not with animal-likeness (bivariate correlation of $-.408^{**}$).

In summary, the results of the participants' ratings

regarding the expectations of the tasks performed by human-like robots or animal-like robots, respectively, are for the most parts conform with the matching hypothesis [39]. The used definitions of the application fields of business, research, healthcare, personal assistance, teaching, caregiving, and public assistance require lots of social activities that are usually done by humans. For companion, pet, toy, and entertainment applications there is no necessity for a human body or human-like interaction. Moreover, many commercial entertainment and toy robots actually have an animal-body which also may have an influence on the participants' expectations.

To sum up, the results show two obvious groups of application fields where the visual appearance of robots were in relation with the expected tasks. The first group includes the application fields security, business, research, healthcare, personal assistance, teaching, transport, caregiving, and public assistance. These strongly correlate to a human-like/functional-like appearance. The other group consists of the application fields entertainment, pet, toy, and companion and strongly correlates with an animal-like appearance. The insights on appearance are deepened in the next section.

4.2 Results regarding Visual Appearance

Repliee Q2 (4.65), Asimo (3.75), and Barthoc Jr. (3.12) were seen as most human-like and in contrast Paro (1.26) and Aibo (1.37) seemed to be least human-like. The robots Robovie, Asimo (3.96), Robovie (3.90), Pearl (3.81), Barthoc (3.72), Kismet (3.72) and BIRON (3.62) were rated to have a functional or technical appearance. Paro (2.00), Keepon (2.11), and Leonardo (2.11) were rated not to have such a technical appearance because in contrast to the technical appearing robots these robots do not have any observable technical features. For the participants, Paro (4.58), Leonardo (4.11), and Aibo (4.05) appeared to have an animal-like shape. Despite its name, the iCat was not rated that high regarding animal-likeness (3.17) which is probably due to the fact that the robot is only a torso. Least animal-like appeared BIRON (1.13), Barthoc Jr. (1.18) Repliee Q2 (1.24), and Asimo (1.27).

We want to point out two major findings with respect to the visual appearance of social robots: human-like robots are not animal-like (bivariate correlation of $-.383^{**}$), but both human-like and animal-like robots may additionally have a functional/technical appearance. We found a correlation between human-likeness and functional/technical design (bivariate correlation of $.201^{**}$). In the case of Asimo, the participants chose human-likeness as well as functional/technical design to describe the appearance. Therefore, the conclusion is that a functional or a technical appearance is not a distinctive class regarding the visual appearance of robots which led the participants to discordant results.

On the contrary we found a negative correlation between animal-likeness and functional/technical design (bivariate correlation of $-.342^{**}$). This is due to the fact that most animal-like robots in the study have no technical features, for example, because the joints are covered by fur. However, for Aibo this is different, showing that both technical/functional

Table 2. Influence of knowledge on the evaluation of robots

robot	item	Mean do not know robot	Mean know robot	F value	significance
Asimo (df=1, 122)	like	3.06	3.54	5.544	.020*
	own	2.36	3.19	9.785	.002**
	attractive	2.72	3.39	8.722	.004**
Kismet (df=1, 120)	like	2.53	3.33	6.376	.013*
	own	2.09	3.00	11.036	.001**
	attractive	2.16	2.71	3.313	.071
Aibo (df=1, 121)	like	3.05	3.70	8.554	.004**
	own	2.52	3.28	9.513	.003**
	attractive	2.86	3.45	7.300	.008**

and animal-like appearance do not necessarily exclude each other. In the case of Aibo, participants rated the visual appearance either animal-like or technical. They clearly decided for one property to describe Aibo's appearance. Therefore, animal-likeness and technical appearance do not correlate (-.007).

Human-likeness and animal-likeness do have a definite representamen while a functional/technical appearance might be a property but not a category. Human-likeness represents the similarity to human beings and animal-likeness represents the similarity to animals. But in contrast to Fong et al. [3], functional design is not a well defined term and distinctive class of visual appearance in robotics because it is not clear what kind of artifact it actually represents. Hence, Asimo has a human-like shape as well as a functional/technical appearance which is due to the visible joints, screws, and mechanical surfaces. The same is true for other robots (e.g., Aibo, Barthoc Jr.).

4.3 Results regarding Sympathy

Finally we analyzed the relationship between items on likeability and attractiveness. The participants would most likely use the robots Pearl (2.99), Asimo (2.95), and Aibo (2.90) and they would least like to use Barthoc Jr. (2.21). They most liked Paro (3.41), Asimo (2.95), and Aibo (3.26) and they did not like Barthoc Jr. (2.12). Further they rated Paro (3.17), Aibo (3.20), and Asimo (3.08) to be most enjoyable and they assessed BIRON (2.35) and Barthoc Jr. (2.27) to be least enjoyable. In general the scores whether the participants would like to own the robots were low (2.42), but they would most like to have Aibo and Asimo. Finally, the participants found Paro (3.21), Aibo (3.05), Repliee Q2 (3.02), and Asimo (3.02) most and Barthoc Jr. (1.90) least attractive. In conclusion likeability, enjoyability, ownership, attractiveness, imagination to use a robot are all highly correlated for all robots (bivariate correlations from .671** to .833**). The participants especially preferred the robots that they rated as being more attractive to them.

Additionally, it is interesting to know whether participants who knew the robots evaluated them differently. In psychology it has been proven experimentally that the degree of familiarity

has an influence on the ratings of attractiveness. Just coming together for several short times increases the evaluation of attractiveness due to the fact that people simply prefer things they already know [41, 42].

For Asimo, Kismet, and Aibo a one-way ANOVA was calculated. These robots were chosen because they were familiar to more than 15% of the subjects answering the questions about them: 46% of the people knew Asimo, 36.5% knew Aibo, and 17.5% knew Kismet. The same as in social psychology was found to be true for robots in this study: the participants who listed to know the robots found the robots significantly more attractive (except of Kismet), likeable and they would also significantly more like to own these robots (see Table 2). In the case of Kismet, the results were more imprecise as in the cases of Asimo and Aibo due to the fact that only 17.5% of the people knew the robot.

V. CONCLUSION

183 participants rated how appropriate thirteen categories of applications are for twelve different robots. They only received information about the robot's general functions combined with a video that displayed the robot.

Taken together, the findings of the present study show that the visual appearance of social robots is a significant predictor of the participants' attributions of applications. Particularly the distinction of human-likeness and animal-likeness led the naïve participants to have distinctive expectations of what applications match the robot's capabilities. Human-like robots were expected to be used in the application fields of security, business, research, healthcare, personal assistance, teaching, transport, caregiving, and public assistance. Animal-like robots were expected to serve as companions, entertainers, toys, and robotic pets.

Additionally, the results showed strong correlations among the attributed attractiveness, whether people would like to own the robot, if they liked the robot, how enjoyable the robot was, and if people could imagine to use the robot. Therefore, the attractiveness of social robots is a predictor of the values that are attributed to them.

Future studies should seek to identify further visual factors influencing the attribution of applications. Moreover, this paper only treated twelve different robots with completely distinctive shapes. A follow-up study with more robots could test the influence of more subtle differences. It would be interesting to know if a specific human-like or animal-like appearance is favoured, if attractiveness also has influences on the attribution of specific qualities within application fields, and how specific knowledge about robots influences the attributions of applications, attractiveness, and likability.

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