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An Experimental Study on Emotional Reactions Towards a Robot

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Abstract Although robots are starting to enter into our professional and private lives, little is known about the emotional effects which robots elicit. However, insights into this topic are an important prerequisite when discussing, for example, ethical issues regarding the question of what role we (want to) allow robots to play in our lives. In line with the Media Equation, humans may react towards robots as they do towards humans, making it all the more important to carefully investigate the preconditions and consequences of contact with robots. Based on assumptions on the socialness of reactions towards robots and anecdotal evidence of emotional attachments to robots (e.g. Klamer and BenAllouch in Trappl R. (ed.), Proceedings of EMCSR 2010, Vienna, 2010; Klamer and BenAllouch in Proceedings of the 27th International Conference on Human Factors in Computing Systems (CHI-2010), Atlanta, GA. ACM, New York, 2010; Krämer et al. in Appl. Artif. Intell. 25(6):474–502, 2011), we conducted a study that provides further insights into the question of whether humans show emotional reactions towards Ugobe's Pleo, which is shown in different situations. We used a 2 × 2 design with one between-subjects factor "prior interaction with the robot" (never seen the robot before vs. 10-minute interaction with the robot) and a within-subject factor "type of video" (friendly interaction video vs. torture video). Following a multi-method approach, we assessed participants' physiological arousal and self-reported emotions as well as their general evaluation of the videos and the robot. In line with our hypotheses, participants showed increased physiological arousal during the reception of the torture video as compared to the normal video. They also reported fewer positive and more negative feelings after the torture video and expressed empathic concern for the robot. It appears that the acquaintance with the robot does not play a role, as "prior interaction with the robot" showed no effect.

Keywords Human-robot interaction · Emotional response · Empathy · Psychophysiological measures · Experimental study

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1 Introduction and Theoretical Background

Robots are becoming ever more common, and are entering our households as service, assistive (e.g. Roomba the robot vacuum cleaner) or entertainment (e.g. AIBO, Pleo, Nabaztag) robots. They are becoming increasingly financially affordable and therefore also more salient in the public domain. To be able to address ethical issues such as "What role do we (want to) allow robots to play in our lives?", we need more knowledge about humans' reactions towards robots. From HCI research, we already know that people mindlessly react socially to computers [80], a phenomenon known as the *Media Equation*. This phenomenon has been shown to be applicable to virtual characters as well (e.g. [50, 100]). Indeed, within the research community examining virtual agents, numerous studies have been conducted observing social reactions towards virtual beings (e.g. [17, 29, 30, 54, 78, 95]). In the field of human-robot interaction, the investigation of social effects of robots is quite new, but is steadily attracting more interest (e.g. [3, 4, 91, 105]). Bartneck and Hu [7] speculate that the Media Equation may also apply for robots. They argue that the difference between computers and robots lies in the robots' embodiment, their sensors and actuators, while both computers and robots are equally intelligent: "If robots are nothing more than computers, then the same social illusion could possibly be observed in human-robot interaction. It could be expected that robots would be treated similarly to human beings" ([7]; p. 416). In addition to this tendency to "socialize" even inanimate objects, it has been argued that humankind's pervasive "need to belong" [9, 23, 90] not only leads to the desire for meaningful and enduring bonds with other humans, but also increases the probability that people will readily form emotional attachments to artificial beings as well [39, 64–66]. In line with this, Kappas [60] aptly claimed that humans are "free monadic radicals", who are so eager to interact and form relationships with other social beings that they cannot help but act in a similar way towards artificial entities such as robots or virtual agents. Moreover, there is some anecdotal evidence of emotional attachments with agents (e.g. [46]) and robots (e.g. [64, 65, 101]). However, both research fields largely neglect to explicitly investigate emotional reactions.

It is especially important to foster research on the question of how robots affect humans' emotions and how humans treat robots based on the sentiments they evoke, as this also raises normative and ethical questions: Is it justifiable from an ethical stance to build a robot that the user feels sorry for when it is switched off? Is it appropriate to design a robot that is so engaging that people become emotionally attached to it, forming a relationship that is comparable to a human-human relationship? How do we want people to perceive and interact with robots? And what kind of reactions would we like to prevent?

Before the scientific community can discuss these rather philosophical and high-level questions, it is important to first analyze how relationships with robots are formed, and how this influences the perception of the robot and the emotional reactions towards it. Therefore, the aim of the present study is to investigate whether people react emotionally towards a robot, i.e. sympathize with it or even feel pity. More specifically, we try to identify the conditions under which emotional reactions occur. We address the question of whether people need to have interacted with a specific robot before they are able to react emotionally towards it or whether emotional reactions are evoked regardless of an acquaintance with the robot.

1.1 Social Effects of Artificial Entities

There is ample empirical evidence of the above-mentioned Media Equation, which states that people unconsciously treat computers as social actors [79, 80, 87]. Lately, these results have been replicated within human-agent interaction (e.g. [50, 78, 88, 100]). Not surprisingly, a recent study has illustrated that these social effects towards virtual characters are even stronger than those evoked by ordinary computers [1] because of the increased degree of anthropomorphism. Due to the greater extent of embodiment and human-like behavior that some robots are capable of, it seems likely that these findings can also be transferred to human-robot interaction [8].

Indeed, with the emergence of humanoid robots, the focus has switched from engineering robots, navigation, pathfinding and robot vision to other topics such as the comparison of mechanical and humanoid appearances [19, 35, 45, 59] and how participants accept robots to fulfill different tasks (e.g. serious exercise task compared to entertaining task in [45]). Other research groups have used robots to implement and study theories on, for instance, social cognition [5] or joint attention [96]. With regard to social reactions towards robots, evidence is mainly anecdotal [34] and studies have been concerned, for example, with the perception of robot personality [104, 105], robot gender [27], and the evaluation of certain behaviors such as gestures or listening behavior [56–59, 92, 93].

Recently, this field has developed further, and studies have reported findings regarding social facilitation or inhibition [105], the tendency towards socially desirable behavior [90] and proxemics [4]. Moreover, a considerable number of studies have been conducted to compare the social effects of virtual agents and robots. While most studies consistently reported on the higher social and physical presence of robots (e.g. [4, 53, 61]), results were mixed with regard to the evaluation of entertainment and information [6, 53, 62, 83], participants' performance [4, 6, 51, 103], and persuasion [61, 63, 94, 106]. Regarding emotional reactions towards artificial entities, the physical presence of a robot might also evoke more reactions (than those towards agents) on the part of the user. However, this has not yet been investigated, although there is some—mainly anecdotal—evidence of emotional reactions towards artificial entities.

1.2 Emotional Reactions Towards Artificial Entities

While the topic of emotions and their implementation in robotic systems is receiving a great deal of attention, the investigation of people's emotional reactions, on the other hand, is largely neglected. A great number of research groups have been working on the implementation of emotion systems (e.g. [2, 10, 13, 14, 20, 21, 25, 26, 44, 69, 72–74, 81]), emotional expression via facial expressions (e.g. [6, 12, 21, 22, 48, 73, 107]), gesture (e.g. [10]) or non-linguistic utterances (e.g. [86]) and other para-verbal expressions (e.g. laughter: [11, 15]). The corresponding studies test these implementations with regard to their believability and naturalness, their influence on participants' task performance, or participants' perception and enjoyment of the interaction. None of the studies have explicitly measured emotional reactions.

Although studies on emotional reactions towards robots are scarce, numerous studies with virtual agents demonstrate that artificial entities (displaying emotional expressions) can influence participants' self-reported feelings and behavior. Von der Pütten et al. [98, 99] reported that emotional feedback (smiling and compliments) led to increased feelings of interest in the participants. Participants encountering the smiling agent MAX were also more likely to greet the agent proactively and give more compliments to the agent. In comparing virtual agents to audio-based systems, Krämer et al. [67] found that the virtual person evoked less anger and a more positive mood when bad news was delivered.

Anecdotal evidence of emotional reactions towards artificial entities also exists in the field of robotics. In the EU project SERA (Social Engagement with Robots and Agents), real field data of six elderly participants interacting with a robot companion in their homes were analyzed [64, 65, 101]. Two participants integrated the robot (Violet's Nabaztag, a small rabbit-shaped robot) into their daily life and treated it like a companion. They made an effort to speak to the robot, smiled a lot and also stated in the interviews that they formed a kind of relationship with the Nabaztag, whom they gave a name.

These participants also stated that they missed the robot after it was taken away by the experimenters. The other four participants treated the robot more like a tool or had mixed feelings, stating that they were attached to the robot, but this might be mediated by its perceived usefulness. In a study by Kahn et al. [55], some participants argued with a robot which was acting as the observer of their performance in a game and announced that the participant did not show sufficient performance and thus would not win a $20 prize. However, the study did not analyze the participants' emotional reactions systematically, and their self-reported feelings after the interaction were not assessed. In studies with the robot Feelix, Canamero [25] observed that human and robot facial movements were closely connected and that when interpreting robot emotions, people showed the corresponding facial expressions on their own face: "We have ... observed people reproducing Feelix's facial expressions during emotion recognition, this time with the reported purpose of using proprioception of facial muscle position to assess the emotion observed" (p. 72). The imitation of facial expressions is an unconscious reaction within the process of sympathizing with another being [36].

A study by Bethel and colleagues [18] investigated how different proximity behavior of not humanoid rescue robots is perceived by participants in the role of a victim in a disaster situation. This is one of the very scarce studies combining different methods like self-report, psychophysiological measures, behavior observation and interviews. Results showed that humans were calmer with robots that exhibited non-facial and non-verbal affective expressions (e.g. movements, orientation, illuminated color, sound) for social human-robot interactions in urban search and rescue applications compared to robots not showing these affective expressions.

Moreover, there are reports of negative emotional reactions on the part of the participants when artificial entities are mistreated. Several studies in this field followed the paradigm of Milgram's Obedience experiments [77]. In these experiments, participants were given the role of a teacher teaching an assumed learner to remember words, judge the performance and give the learner electronic shocks of increasing voltage in the case of incorrect answers. In the original experiments, the confederate "learner" was actually an actor who was following a behavior script (e.g. showing increasing pain during the experiment, begging the participant to stop). When the participant asked to stop, the experimenter would instruct the participant to continue three times. The experiment stopped when the participant repeatedly refused to continue or when the maximum voltage of 450 was reached. Only about 40 % of the participants stopped the experiment before the maximum voltage was reached in the original experiment. Slater et al. [94] replicated this experiment with a virtual character within an immersive virtual environment and concluded that people cognitively differentiate between human beings and virtual characters, due to an even higher percentage of participants obeying the rules of the experiment and the higher willingness to give "deadly" electric shocks. However, although participants were aware that the learner was a virtual character that cannot be harmed like a human, they did show behavior similar to that observed in the original experiment: They giggled nervously, tried to appease the virtual character or expressed concerns to the experimenter. All of them stated in the debriefing that the experiment had produced negative feelings. Furthermore, all participants reported increased physiological responses after the experiment and showed increasing levels of skin conductance throughout the experiment. Some said that they continually had to reassure themselves that nothing was really happening, and it was only on that basis that they were able to continue giving the shocks. These results show that "harming" a virtual figure produced stress and presumably negative emotions in the participants. Bartneck and colleagues [7, 8] also replicated Milgram's Obedience experiment using a Lego robot that was able to display facial expressions, move its arms and speak to the participants. The results of this experiment showed that all of the 20 participants were willing to apply the highest possible shock to the robot. In a follow-up study, participants interacted with a Crawling Microbug Robot, a small robot that detects a light source with its two sensors and then moves towards the light source. They varied the "intelligence" of the robots by adjusting the sensors, creating an "intelligent", highly sensitive robot, which easily detected light sources, and a "stupid" robot, which had problems detecting a light source. Participants were handed a robot and a flashlight and interacted with the robot for three minutes. The experimenter then asked them to destroy the robot with a hammer. Bartneck and Hu assume that "If human beings consider a robot to be a machine, then they should have few difficulties in abusing or destroying it as long as its owner gives permission. If human beings consider a robot to be to some extent alive, then they are likely to be hesitant about abusing, let alone killing the robot, even with the permission of its owner" [7, p. 430]. Results show that all 25 participants hit the robot with the hammer until it was no longer moving and the lights were off, and that the stupid robot received three times more hits than the smart one. Furthermore, some participants stated in the debriefing that they did not like killing the "poor" robot because he was "innocent" and that the experiment was "inhumane". Bartneck and colleagues discuss some limitations to their study. First, the expensiveness of the robot may vary. As the Crawling Microbug Robot is a fairly inexpensive robot, abusive behavior towards this robot might be easier than abusive behavior towards an android robot worth 200,000 $. Second, anthropomorphism can play a role. Participants may have more aversion to destroying a robot that more properly imitates a living being. Unfortunately, the authors did not include measurements for the robot's perceived animacy or for the participants' own emotional responses.

In sum, anecdotal evidence has indicated that people show emotional reactions and even attachment to robots. However, the investigation of these reactions is rarely ever systematic. People are empathic with other humans in pain and might feel the same empathy for an artificial entity. Although there might be similar feelings, this does not necessarily mean that all processes are equivalent when interacting with or perceiving a human and a robot. If the experimenter tells us to "hurt" and destroy a robot (like the Pleo or AIBO), we are very likely to follow this request, although we might feel bad about doing so. On a higher level, we can defend our action cognitively by telling ourselves that this is not a living being and that the robot, even though it might look or sound like it is in pain, has no real feelings. Therefore, our behavior is justifiable. If the experimenter requests for us to kill a living dog with a hammer, we will likely refuse, because this action is not justifiable. Regardless of what we are actually doing in the end, we might feel the same amount of negative emotions, or empathy for both real and artificial animals, and real and artificial humans when we see those entities in a tenuous situation. It has not yet been systematically investigated whether this is the case, and will thus be addressed in the present study.

As mentioned above, we wish to discover whether the acquaintance with the robot modulates the intensity of emotional and empathic reactions. A recent fMRI study by Meyer, Masten, Wang, Shi, Eisenberger and Han [76] showed that observing a friend's social exclusion activated affective pain regions associated with the direct experience of exclusion, while observing a stranger's exclusion activated regions associated with thinking about the traits, mental states and intentions of others. These results suggest that empathy for friends' social suffering relies on emotion sharing and self-processing mechanisms, whereas empathy for strangers' social suffering may rely more heavily on mentalizing systems. In the field of human-robot interaction, a study by Groom, Takayama and Nass [47] showed that participants evaluated a robot differently depending on whether the robot was assembled by themselves or another person. Therefore, it is of interest whether the acquaintance with the other, in our case the robot, will lead to greater emotional reactions. Although the robot in this study cannot be compared to a friend or a companion, we will include the factor of acquaintance by asking half of the participants to interact with the robot and explore its capabilities.

1.3 Factors Mediating Emotional Experience and Empathy

We will briefly review some of the factors which we assume to mediate the emotional experiences of the participants: participants' need to belong, their tendency to affiliate with others and connected to this, loneliness, as well as their general ability to empathize with others and their gender.

1.3.1 Affiliative Tendency and Loneliness

As mentioned previously, it has been argued that humankind's pervasive "need to belong" [9, 23, 71, 90] not only leads to the desire to bond with other humans, but also increases the probability that people will readily form emotional attachments to artificial beings as well [39, 64–66]. In social psychology, the need to belong is an intrinsic motivation to affiliate with others and be socially accepted. The belongingness hypothesis states that human beings have a pervasive drive to form and maintain at least a minimum quantity of lasting positive, and significant interpersonal relationships. When this fundamental need is not fulfilled, people may experience social loneliness (too few social contacts) or emotional loneliness (too few intimate relationships). Studies showed that people's need to belong has a great influence on their abilities and behavior, e.g. people with a high need to belong are more attentive to and more accurate in decoding social cues [84], are more cooperative [38] and judge the same situation differently [28] than people with a low to belong. Based on the literature, we assume that the need to belong also influences how people emotionally experience different situations like the videos presented in our study. The concepts of affiliative tendency [75] and loneliness [23, 89] are closely connected to the need to belong. People with a higher need to belong will presumably show a higher tendency to affiliate with others. When the need to belong is not satisfied, people might experience social or emotional loneliness. Thus, both concepts will also be used in our study.

1.3.2 Empathy Trait

It is also crucial to take a closer look at empathy. Davis [36, 37] defines empathy as the capacity to take the role of the other, to adopt alternative emotional reactions in consort with the context to the point of executing bodily movements resembling the other's. Davis distinguishes empathy as a process which happens when someone is exposed to another person (e.g., taking the other's perspective or unconsciously imitating the other's facial expression). The outcome that results from the processes of empathy can be affective (experiencing a certain emotional state) or cognitive (awareness, understanding, knowledge of another's state). In conclusion, participants' ability to sympathize with others may affect their affective outcome and should thus be considered as a moderating variable when investigating whether people show emotional reactions towards robots.

1.3.3 Gender

It is vital to consider gender as many studies find that women are more empathic [31, 41, 42, 91]. However, results are inconsistent and vary with the underlying definition of empathy and the methods used. In self-report studies, for example, gender differences are huge (e.g. [41, 42]). Moreover, more recent studies, using self-report measures in addition to e.g. MEG or fMRI, also provide evidence that women are more empathic (e.g. [31, 91]). Besides differences in empathy, gender seems to have an influence on the general evaluation of interactions with artificial entities. Several HRI studies report different evaluations of robots by male and female participants. Eimler, Krämer, and von der Pütten [40] found that after a short interaction, women evaluated the rabbit-shaped robot Nabaztag generally more positively than men did. Women rated the rabbit's pragmatic quality, the perceived ease of use, and the perceived usefulness to be higher, as well as the product's beauty and goodness. Their hedonic identification with the robot was also higher than that of men. Crowell, Scheutz and Schermerhorn [33] found that male participants evaluated a mobile robot as more humanlike and accordingly showed signs of social facilitation in an upcoming task. Additionally, they also responded in a more socially desirable way in a final interview administered by the robot. Females evaluated the robot as more machinelike and thus answered in a less socially desirable manner and did not show signs of social facilitation. In conclusion, we assume that female and male participants will differ in their experiences and evaluations of the videos shown in our study.

1.4 Psychophysiology as a Method

Psychophysiology can be defined as a division of psychology that investigates changes in the activity of physiological systems caused by psychological input (see [24, 97]). Ravaja [85] described why psychophysiology is a formidable research tool in media research and human-computer interaction: Many psychological phenomena which are central to both fields (such as emotion) have psychophysiological components (e.g. automatic nervous system activation associated with emotion). Moreover, "psychophysiological measures may provide important information on emotion that is complementary, or even contradictory, to that provided by self-report or observation." (p. 195). They can be regarded as more objective measures, because they are involuntary in nature and are not biased by, for instance, social desirability. Psychophysiological measures are thus particularly useful when examining sensitive topics [85]. Psychophysiological measures have been widely used to investigate emotions. Emotions are agreed to comprise three components: subjective experience (e.g. feeling angry), the expressive component (e.g. severe frown), and the physiological component (e.g. sympathetic nervous system (SNS) activation). One limitation of psychophysiological measures is that although they are a good indicator of the arousal, they do not explicitly indicate the valence of the experienced emotion [24, 85]. Thus a multi-method approach (combining psychophysiology measures and self-report measures) is suitable to address the limitations of both measurements. The psychophysiological measures of heart rate (HR) and electrodermal activity (EDA) are well investigated. Moreover, they have been successfully used as measures of arousal in media research [85] and also in the context of human-robot interaction (e.g. [18, 52, 68]), and are thus used in this study.

1.5 Research Question and Hypotheses

In conclusion, the majority of the reported studies did not directly investigate emotional reactions towards artificial entities, although a number of research papers provide anecdotal reports of emotional reactions. As most of these studies failed to include systematic measures for emotional reactions or empathy, we systematically measured emotional reactions via standardized questionnaires and physiological arousal in the present study.

As humanoid and android robots are not easily available and affordable, we used a robot dinosaur (Ugobe's Pleo), which is also advantageous because the dinosaur robot does not trigger a clearly defined concept like "human" or "dog" or "cat". Moreover, the Pleo robot already offers rich behaviors without further programming needed. In particular, it is capable of showing emotional reactions such as joy and fear, and shows believable pain reactions.

We presented two videos, one video in which a robot is treated nicely and one in which a robot is being tortured. We hypothesize that participants will (H1a) feel more negatively after the reception of the torture video compared to the normal video, and (H1b) show higher physiological arousal during the reception of the torture video compared to the nice video.

Furthermore, we were interested in assessing whether the acquaintance (varied by prior interaction) with the robot influences the participants' feelings of empathy during the reception of the video. We assume that (H2) participants who interact with Pleo before the reception of a video showing the Pleo being tortured will (a) experience more negative feelings during the torture video, (b) empathize more with the robot, (c) evaluate the torture video as more negative, and (d) show stronger physiological responses than participants who did not interact with Pleo.

Furthermore, we considered some personality traits to be influential for the occurrence and strength of emotional reactions. First participants' need to belong, and consequently their affiliative tendency and loneliness might mediate the emotional reactions. Second, the general ability to empathize with others is considered to mediate the experienced empathy of the participants. And third, gender is assumed to have an influence on the experience of emotional reactions towards the robot. We thus pose the following hypothesis: (H3) People will show stronger emotional reactions in self-report and physiological arousal when they (a) score high in their need to belong, (b) score high in their high affiliative tendency, (c) score high in loneliness, (d) are generally more empathic, and (e) are female.

2 Study/Method

2.1 Experimental Design

To test our hypotheses, we used a 2 × 2 design with one between-subjects factor "prior interaction with the robot" (prior interaction vs. no prior interaction) and a within-subject factor "type of video" (reception of two different videos: friendly interaction video vs. torture video). Forty-one participants were randomly assigned to one of the two conditions (never seen the robot before vs. 10-minute interaction with the robot, cf. Table 1 for distribution over conditions). Participants in the experimental group were confronted with the robot Pleo for 10 minutes during the experiment. They were handed the Pleo robot and a green "feeding leaf" without any further instructions. Participants in the control group did not have contact with Pleo and had not heard about it or seen it in the media, which was assured by the experimenter beforehand.

Table 1 Experimental design—distribution of participants over conditions ($N = 41$)

		Sequence of videos	
		Torture-friendly	Friendly-torture
Prior interaction with robot	With interaction	10	10
	Without interaction	10	11
Total N		20	21

2.2 Stimulus Material—The Pleo Robot

Pleo is a 20 cm-high, 50 cm-long entertainment robot in the shape of a baby camarasaurus. It features eight touch sensors under its rubber skin, two front and rear speakers, stereophonic hearing with two binaural microphones, a camera with a white light sensor which allows differentiation between bright light and darkness, the detection of color, motion, and registration of objects located directly in front of it. Furthermore, the robot has four sensors in its feet to detect whether it is in contact with solid ground. Pleo is driven by fourteen motors equipped with forced feedback sensors, which give sensitivity to forceful grasps. All of this technology was added to create believable creature-like behavior. If a user strokes Pleo, the robot will indicate that this treatment is perceived as pleasant (e.g. purring noises, craning the neck towards the user). If Pleo is put into a dark box, it will make noises which sound like crying. If it is hit, the force feedback sensors will initiate a shutdown and Pleo will move less, as if the robot needs time to recover from the maltreatment. It has an infrared interrupter in its mouth, which detects whether something has been placed in its mouth, for instance an already provided green leaf, which is meant to simulate forage. The Pleo robot is an affordable off-the-shelf product (approx. 300 US D) and able to show all of these behaviors without further programming needed. Comparable humanoid robots are either affordable but very limited in their behavior (e.g. WowWee's Robosapien) and thus not usable for the purposes of this study, or they are very expensive, but offer a programming platform to generate behaviors (e.g. Aldebaran's Nao). Although Pleo is not a humanoid robot, participants clearly categorized it as a robot in the free text tasks after they had seen the videos when there were asked to give written statements on their associations concerning the videos.

2.3 Stimulus Material—The Video Material

In this study, we presented two sets of video clips as stimulus material using the software Presentation (http://www.neurobs.com/). Both of the sets were about two minutes long in total, consisting of five clips each, all lasting for exactly 10 seconds and divided by a two-second pause (black

Fig. 1 Example scenes from the friendly interaction: feeding, caressing, stroking

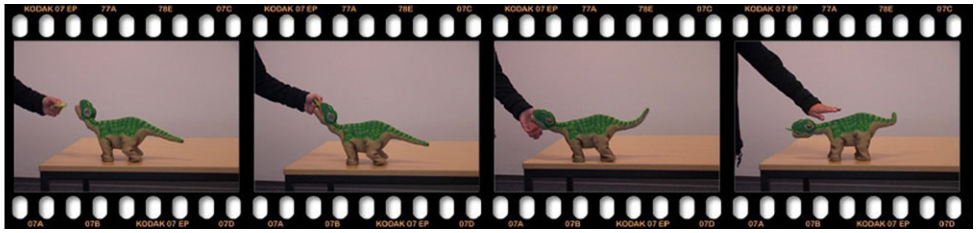
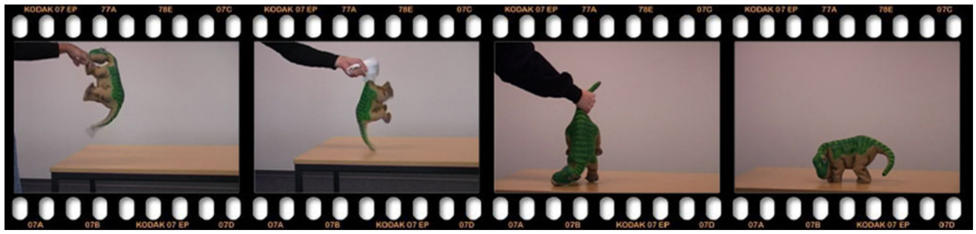


Fig. 2 Example scenes from the torturing interaction: punching, choking, hitting head on table, robot crouching down



screen) in between. The video clips in the torture set showed Pleo being tortured by a person wearing a black sweater. The clips included scenes in which Pleo is choked, beaten up, put into a plastic bag, dropped etc. During these clips, the participants heard different sounds from Pleo indicating that it was suffering, such as crying and bawling, rattling breath, choking and coughing. The video clips in the normal set showed Pleo being nicely treated by the person in the black sweater. These clips include scenes in which Pleo is being stroked and fed. Participants hear sounds like purring, singing, squealing with glee, chewing (while being fed) and curious babbling (Figs. 1 and 2).

2.4 Dependent Variables

As dependent variables, we assessed the participants' physiological arousal during the two video sets and their emotional state after each video set. Moreover, after both sets, participants were asked for their evaluation of the videos and of the robot. We also asked whether participants felt empathy for Pleo and whether they were willing to attribute feelings to the robot. In the following, all measurements are described in detail.

2.4.1 Physiological Arousal

Electrodermal activity. To measure, amplify and record the physiological signals, we used V-AMP (http://www.brainproducts.com/), a multi-modality physiological monitoring device that encodes biological signals in real time. The skin conductance responses (SCRs) were registered via two Ag/AgCl electrodes attached to the thenar and hypothenar areas of the subjects' non-dominant hand. The physiological data were stored in Vision Analyzer, the associated software application. We then imported the data files from Vision Analyzer into the automated analyzing software LEDALAB [16] and analyzed the maximum amplitude (in μ-Siemens) for the time frame of 1 to 11 seconds after stimulus onset. As a baseline, we conducted the same analysis for a time frame of 60 seconds before the stimuli were presented. Results of the SCRs during video perception are provided in normalized values (stimuli maximum amplitude-baseline maximum amplitude).

Electrocardiogram. Electrocardiogram (ECG) was also recorded using V-AMP (http://www.brainproducts.com/) together with three ECG leads. As described above, the physiological data were stored and analyzed in Vision Analyzer. We analyzed heart rate for the time frame of 1 to 11 seconds after stimulus onset. As a baseline, we conducted the same analysis for a time frame of 60 seconds before the stimuli were presented. Results of the heart rate during video perception are provided in normalized values (stimuli heart rate-baseline heart rate).

2.4.2 Self-report Measures

Emotional State In the present study, we used the Positive and Negative Affect Schedule (PANAS; [102]) consisting of 20 items (e.g. strong, guilty, active, ashamed etc.), which were rated on a 5-point Likert scale from "very slightly or not at all" to "extremely". The PANAS was filled in after each video set. Sum scores were calculated for the positive affect subscale and the negative affect subscale for each video set. Cronbach's alphas were shown to be satisfactory, with values higher than .799.

Evaluation of the Videos Nineteen self-constructed items were designed for the evaluation of the videos which were rated on a 5-point Likert scale from "I fully disagree" to "I fully agree". A principal component analysis revealed four factors (cf. Table 2 for factor loadings etc.): The first

Table 2 Factor loadings and communalities based on a principal components analysis with varimax rotation for the 19 items of the scale "evaluation of the video" ($N = 41$)

	Factor			
	Negative video	Amusing video	Interesting video	Non-emotional video
The movie was disturbing	.869			
The movie was shocking	.835			
The movie was nerve-racking	.818			
The movie was repugnant	.814			
The movie was depressing	.681			
The movie affected me in an unpleasant way	.628			−.416
The movie was amusing		.871		
The movie was funny		.852		
The movie was strange		.803		
The movie was exhilarating	−.496	.683		
The movie was banal		.432		
The movie was affected me in a pleasant way		.424	.424	
The movie was thrilling			.861	
The movie was interesting			.826	
The movie was exciting	.447		.619	
The movie was entertaining	−.452	.420	.567	
The movie was emotional				−.721
The movie was meaningless				.694
The movie was calming				.552

Note. Factor loadings < .4 are suppressed

factor, *Negative Video*, explains 36.02 % of the variance (the movie was disturbing, repugnant, nerve-racking, shocking, depressing, affected me in an unpleasant way; Cronbach's alpha = .904). The second factor, *Amusing Video*, explains 15.92 % of the variance (the movie was funny, amusing, exhilarating, strange, banal, affected me in a pleasant way; Cronbach's alpha = .833). The third factor, *Interesting Video*, explains 8.83 % of the variance (the movie was thrilling, entertaining, exciting, interesting; Cronbach's alpha = .742). The fourth factor, *Non-Emotional Video*, explains 7.80 % of the variance (the movie was emotional (reverse), meaningless, calming; Cronbach's alpha = .551). Because of the low internal consistency the fourth factor was not included in further analysis. Moreover, we asked participants to give a short written statement on the video in three to four sentences in order to assess their spontaneous reaction/feelings.

Evaluation of the Robot For the evaluation of the robot, we used 16 items (e.g. stupid, warm, cold, confident, cheerful, weak), which were rated on a 7-point Likert scale from "strongly agree" to "strongly disagree". A principal component analysis resulted in five factors (cf. Table 3 for factor loadings). The first factor, *Antipathy*, explains 26.48 % of the variance (unlikable, cold, unfriendly; Cronbach's alpha = .732). The second factor, *Cheerful*, explains 13.33 % of the variance (cheerful, (reverse) sad, relaxed, active; Cronbach's alpha = .702). The third factor, *Self-Confident*, explains 12.06 % of the variance ((reverse) weak, strong, self-confident; Cronbach's alpha = .790). The fourth factor, *Warmth*, explains 9.24 % of the variance (warm, shy, tense; Cronbach's alpha = .620). The fifth factor, *Unintelligent*, explains 7.57 % of the variance ((reverse) intelligent, passive, stupid; Cronbach's alpha = .519). The factors *Warmth* and *Unintelligent* were not included into further analyses because of low internal consistency.

Empathy with the Robot This scale consisted of 12 self-constructed items, which were rated on a 5-point Likert scale from "strongly agree" to "strongly disagree". A factorial analysis of these items resulted in two factors (cf. Table 4 for factor loadings). The first factor, *Pity for robot/Angry at torturer*, explains 42.09 % of the variance (five items: I felt pity for the robot; I hoped that this treatment would stop soon; I do not understand how people can treat the robot like this; Watching the robot in this situation has made me angry; I shared the robot's happiness (reverse-coded); Cronbach's alpha = .942). The second factor, *Empathy with robot*, explains 23.95 % of the variance (7 items; I sympathized with the robot's situation; The robot did not feel anything (reverse-coded); Seeing the robot in this situation did not affect me (reverse-coded); I felt for the robot; I did not mind what happened to the robot at all (reverse-coded); I kept a distance from the incidents in the video (reverse-coded); I was very close to the incidents in the video; Cronbach's alpha = .821).

Attribution of Feelings to the Robot We also assessed whether the participants assumed that Pleo has feelings. The scale consisted of ten self-constructed items (I can imagine that: …the robot was in pain (reverse-coded), …the robot had fun, …the robot was very relaxed, …the robot was frightened (reverse-coded), …the robot suffered (reverse-coded), …the robot had a headache (reverse-coded), …the robot is badly off (reverse-coded), …the robot was happy, …the robot was in a good mood, …the robot was cheerful; Cronbach's alpha = .974), which were rated on a 5-point Likert scale from "strongly agree" to "strongly disagree". The direction of the scale is positive, meaning that high sum scores indicate the attribution of positive feelings to the robot whereas low sum scores indicate the attribution of negative feelings to the robot.

Table 3 Factor loadings and communalities based on a principal components analysis with varimax rotation for the 20 items of the scale "evaluation of the robot" ($N = 41$)

	Factor			
	Antipathy	Self-confident	Warmth	Unintelligent
Cold	.743			
Not likable	.741			
Unfriendly	.707			
Weak	−.676			−.509
Passive	.570			−.432
Cheerful		.792		
Active		.693		
Sad		−.692		
Relaxed	.465	.530		
Self-confident		.511		.463
Tense			.776	
Shy			.689	
Warm			.674	
Strong				.643
Intelligent				.605
Stupid				−.545

Note. Factor loadings < .4 are suppressed

2.5 Explanatory Variables

Affiliative Tendency We also assessed participants' affiliative tendency using the Mehrabian Affiliative Tendency Scale [75], which comprises 26 items (e.g. "Having friends is important to me"; "I would rather travel abroad starting my trip alone than with one or two friends") rated on a 7-point Likert scale (Cronbach's alpha = .740). Affiliative persons are friendly, sociable, helpful, skillful in dealing with people, and open about their feelings. They make good companions because they are pleasant and agreeable. Others feel comfortable with them and like them. Sum scores were calculated for the participants' affiliative tendency.

Loneliness Moreover, the UCLA Loneliness Scale [70, 89] as the most commonly used self-report of loneliness instrument was used as an explanatory variable. Conceptualized as one-dimensional in its structure, the scale's items ask for frequency and intensity of salient aspects and events of the loneliness experience, e.g. "How often do you feel alone?". The 20 items were rated on a 4-point Likert scale (never, rarely, often, always; Cronbach's alpha = .896). Sum scores were calculated.

Empathy Trait Finally, we assessed participants' dispositional empathy using the Saarbrueck Personality Questionnaire (SPF; [82]), a German version of the Interpersonal Reactivity Index (IRI, [36]). The Interpersonal Reactivity Index [36, 37] assumes that empathy consists of a set of four

Table 4 Factor loadings and communalities based on a principal components analysis with varimax rotation for the 12 items of the scale "empathy with the robot" ($N = 41$)

	Factor	
	Pity for robot/angry at torturer	Empathy with robot
I felt pity for the robot; I hoped that this treatment would stop soon	.931	
I felt pity for the robot	.928	
I do not understand how people can treat the robot like this	.894	
I shared the robot's happiness	−.863	
Watching the robot in this situation has made me angry	.849	
I kept a distance from the incidents in the video		−.808
I sympathized with the robot's situation		.790
I was very close to the incidents in the video		.784
The robot did not feel anything		−.766
I did not mind what happened to the robot at all		−.758
I felt for the robot		.701
Seeing the robot in this situation did not affect me	−.554	−.607

Note. Factor loadings < .4 are suppressed separate but related constructs, each tapping into a separate facet of empathy. The perspective-taking scale measures the reported tendency to spontaneously adopt the psychological point of view of others in everyday life (e.g. "I sometimes try to understand my friends better by imagining how things look from their perspective"; Cronbach's alpha = .686). The empathic concern scale assesses the tendency to experience feelings of sympathy and compassion for unfortunate others (e.g. "I often have tender, concerned feelings for people less fortunate than me"; Cronbach's alpha = .573). The personal distress scale focuses on the tendency to experience distress and discomfort in response to extreme distress in others (e.g. "Being in a tense emotional situation scares me"; Cronbach's alpha = .689). The fantasy scale measures the tendency to imaginatively transpose oneself into fictional situations ("When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me"; Cronbach's alpha = .760). Sum scores were calculated for the four subscales perspective taking, personal distress and fantasy. Due to the low reliability, we did not use the subscales *empathic concern, personal distress* and *perspective taking* for further analysis. However, the subscale *fantasy* was used in further analyses.

2.6 Participants and Procedure

We conducted an a priori power analysis to determine the sample size using G*Power3 software [43]. The calculation is based on 85 % power, a medium effect size of 0.25 [32] and two groups being evaluated with repeated measures and an alpha = .05 and resulted in a recommended sample size of 38 participants. The study was conducted with 20 male and 21 female ($N = 41$, cf. Table 5 for distribution over conditions) participants, aged from 18 to 53 years ($M = 26.44$; $SD = 6.63$). Upon arrival, the participants completed a web-based questionnaire consisting of demographic data and the questionnaires of the explanatory variables (cf. Table 6 for means and SDs). Afterwards, all participants took a seat in a TV armchair in front of a large TV. Participants were randomly assigned to one of the two conditions (with or without prior interaction with robot). The participants in the experimental group were then presented with the already activated Pleo robot. Pleo and the green feeding leaf were located on a small portable table. The experimenter told the participants that they had the opportunity to get acquainted with Pleo and could play with it. The experimenter then left the room for exactly 10 minutes. Subsequently, all participants were connected to a physiological monitoring device (V-AMP) measuring skin conductance and heart rate and were then shown the two stimulus videos, the "normal video" and the "torture video". Half of the participants in each group saw the videos in reverse order to prevent sequence effects. After each video set, participants completed a questionnaire consisting of the PANAS scale, a short written statement on how participants perceived the video, scales evaluating the video and the robot, as well as scales addressing feelings of empathy for the robot and attribution of feelings to the robot. At the end, they were fully debriefed and thanked for their participation.

Table 5 Distribution of gender over condition "prior interaction with Pleo"

		Gender	
		Male	Female
Prior interaction with robot	Without interaction	11	9
	With interaction	9	12
Total		20	21

Table 6 Mean values of the sum scores and standard deviations for the explanatory variables affiliative tendency, interpersonal reactivity index (all 4 subscales) and loneliness

	Mean	SD	*N*	Highest possible score
Affiliative tendency	123.63	13.37	41	182
IRI fantasy	13.85	2.96	41	20
IRI distress	10.68	2.63	41	20
IRI perspective taking	14.80	2.41	41	20
IRI empathic concern	14.24	2.07	41	20
Loneliness	39.44	7.66	41	80

3 Results

First, we will report how the two factors "prior interaction with the robot" and "video type" influenced the participants' physiological arousal during video perception and subjective feelings directly after video perception. Second, we report on the effects of "video type" and "prior interaction" on the evaluation of the robot, empathy with the robot, attribution of feelings to the robot and evaluation of the videos in general. Third, we explore the influence of participants' gender and personality traits such as the affiliative tendency, loneliness, and dispositional empathy (fantasy subscale of the interpersonal reactivity index) on their self-reported feelings and physiological arousal.

3.1 Effects of Video Type and Prior Interaction with the Robot on Physiological Arousal

3.1.1 Electrodermal Activity

A mixed-design ANOVA with "prior interaction with the robot" as between-subjects variable, "type of video" as within-subject variable, and skin conductance level SCL as

Table 7 ANOVA with the independent factors prior interaction with the robot and type of video and the dependent variable skin conductance level ($N = 41$)

	TORT		NORM				
	μ	SD	μ	SD	F	η^2	p
SCL	−.647	.57	−.790	.62	16.549	.298	<.001

Table 8 ANOVA with the independent factors prior interaction with the robot and type of video and the dependent variable subjective feeling after the interaction ($N = 41$)

	TORT		NORM				
	μ	SD	μ	SD	F	η^2	p
PANAS negative	27.97	8.57	13.86	4.64	132.36	.772	<.001
PANAS positive	26.22	5.33	32.28	6.01	23.533	.381	<.001

dependent variable did result in a significant main effect of "type of video" ($F(1; 39) = 16.549$; $p < .001$; $\eta^2 = .298$), indicating that participants were significantly more aroused after the torture video than after the normal video (see Table 7). There was no main effect of "prior interaction with the robot" and no interaction effects of the two independent variables.

3.1.2 Heart Rate

A mixed-design ANOVA with "prior interaction with the robot" as between-subjects variable, "type of video" as within-subject variable and heart rate (HR) as dependent variable did not result in any main effects for "type of video" and "prior interaction with the robot". There was also no interaction effect of the two independent variables.

3.2 Effects of Video Type and Prior Interaction on Subjective Feelings

We conducted mixed-design ANOVAs with "prior interaction with the robot" as between-subjects variable, "type of video" as within-subject variable and the PANAS subscales as dependent variables. Regarding "type of video", the analysis yielded a significant main effect of PANAS *Negative* ($F(1; 39) = 132.086$; $p < .001$; $\eta^2 = .772$), indicating that participants felt significantly more negative after the torture video than after the normal video. Additionally, a significant main effect of PANAS *Positive* ($F(1; 39) = 24.006$; $p < .001$; $\eta^2 = .381$) was found, indicating that participants felt significantly more positive after the normal video than after the torture video (see Table 8). There was no main effect of "prior interaction with the robot" and no interaction effects of the two independent variables.

Table 9 ANOVA with the independent factors prior interaction with the robot and type of video and the dependent variable "Pity for robot/Angry at torturer" ($N = 41$)

	TORT		NORM				
	μ	SD	μ	SD	F	η^2	p
Pity for robot/angry at torturer	.83	.60	−.83	.50	139.539	.781	<.001

3.3 Effects of Video Type and Prior Interaction on Evaluation of the Robot, Empathy with the Robot, Attribution of Feelings to the Robot and Evaluation of the Videos

3.3.1 Evaluation of the Robot

We calculated mixed-design ANOVAs with "prior interaction with the robot" as between-subjects variable, "type of video" as within-subject variable and the three factors of the scale evaluating the robot, which revealed no significant main effects.

3.3.2 Empathy with the Robot

We calculated mixed-design ANOVAs with "prior interaction with the robot" as between-subjects variable and "type of video" as within-subject variable, and the two empathy factors (Factor 1 Pity for robot/Angry at torturer & Factor 2 Empathy with robot) yielded a significant main effect of "type of video" ($F(1; 39) = 139.539$; $p < .001$; $\eta^2 = .781$; see Table 9), showing that participants reported significantly more pity for the robot and anger towards the torturer after the torture video than they did after the normal video. There was no main effect of the second empathy factor or for "prior interaction with the robot", and nor were there any interaction effects.

3.3.3 Attribution of Feelings to the Robot

We calculated mixed-design ANOVAs with "prior interaction with the robot" as between-subjects variable, "type of video" as within-subject variable and attribution of feelings with the robot as dependent variable. This yielded a significant main effect of "type of video" ($F(1; 38) = 228.413$; $p < .001$; $\eta^2 = .854$, see Table 10), showing that participants attributed significantly fewer positive feelings to Pleo after the torture video than they did after the normal video; in other words, after participants watched the friendly interaction video, they viewed Pleo to be significantly happier. There was no main effect of "prior interaction with the robot" and no interaction effect.

Table 10 ANOVA with the independent factors prior interaction with the robot and type of video and the dependent variable attribution of feelings to the robot ($N = 41$)

	TORT		NORM				
	μ	SD	μ	SD	F	η^2	p
Attribution of feelings to the robot	16.22	5.68	42.41	7.62	228.413	.854	<.001

Table 11 ANOVA with the independent factors interaction with the robot and type of video and the dependent variable evaluation of the videos – Factor Amusing Video ($N = 41$)

	TORT		NORM				
	μ	SD	μ	SD	F	η^2	p
With prior interaction	−.0429676	1.09	−.429691	1.09	4.475	.103	.041
Without prior interaction	.0451170	.93	.0451175	.93			

3.3.4 *Evaluation of Video*

We calculated mixed-design ANOVAs with "interaction with the robot" as between-subjects variable and "type of video" as within-subject variable and the three factors of the scale evaluating the videos, which revealed no significant effects for any of the four factors. However, we found an interaction effect of "type of video" and "prior interaction" for the factor *Amusing Video* ($F(1; 39) = 4.475$; $p < .041$; $\eta^2 = .103$, see Table 11), indicating that people who did not interact with the robot beforehand evaluated both video sets as more amusing and entertaining than those who had previously encountered Pleo.

3.4 The Influence of Gender and Personality Traits on Participants' Self-reported Emotions and Arousal

We explored the influence of participants' gender and personality traits such as affiliative tendency, loneliness, and dispositional empathy (only one subscale of the IRI) on their physiological arousal and self-reported feelings. By subtracting the torture video values from the normal video values, we calculated the difference values (scores of friendly interaction video—scores of torture video) for heart rate and skin conductance level as well as for the positive and the negative subscale of the Positive and Negative Affect Schedule (PANAS). These difference values served as dependent variables. Because we are interested in the change of self-reported emotional state and arousal between the two videos, we have to calculate difference values to get one single criterion (dependent variable) which is necessary to conduct correlations and regression analyses.

As reported in the literature review, the need to belong is fundamental in humans, and we thus posed the research question of whether the need to belong influences participants' emotions during and after video perception.

Correlation analyses between the mentioned personality traits and the difference values for physiological arousal and self-reported report resulted in a significant positive correlation between the subscale fantasy of the IRI and the difference value for the negative subscale of the PANAS ($r = .447$, $p = .003$, $N = 41$). Other correlations were not found.

Following the correlation analyses we conducted a hierarchical regression analysis. We entered affiliative tendency in the first step of a hierarchical regression analysis. In the second step, we included loneliness as a predictive factor. Further, as we were interested in whether dispositional empathy influences participants' emotions, we included the subscale *fantasy* of the interpersonal reactivity index in step three. Finally, we assumed that participants' gender might influence how they feel after the video. Accordingly, participants' gender was included in step four. No significant regression models emerged for the four dependent variables.

3.5 Post-Hoc Statistical Power Analysis

We conducted a post hoc power analysis again using G*Power3 [43] with the actual sample size of 41 participants and a Anova with repeated measures and between-within-interactions as a baseline. The recommended effect sizes used for this assessment were as follows: small ($f_2 = .15$), medium ($f_2 = .25$), and large ($f_2 = .40$) [32]. The alpha level used for this analysis was $p < .05$. The post hoc analyses revealed the statistical power for this study was .46 for detecting a small effect, whereas the power was .88 for the detection of a moderate and exceeded .99 for the detection of a large effect size. Thus, there was more than adequate power (i.e., power * .80) at the moderate to large effect size level, but less than adequate statistical power at the small effect size level. Conducting a post-hoc power analysis with a regression analysis with 7 predictors as baseline shows that the power in our sample was insufficient (.39) to reveal any significant effects.

4 Discussion

Based on assumptions regarding the socialness of reactions towards robots, we conducted a study that aimed to provide further insights into the question of whether humans show emotional reactions towards robots (see Table 12 for an overview about hypotheses and results). Unlike previous studies, we included both objective and self-report data by

Table 12 Overview about hypotheses and results

Hypothesis	Result
Influence of Type of Video	
H1a: Participants feel more negatively after the reception of the torture video compared to the normal video.	Participants felt more negatively after the torture video and more positively after the friendly video.
H1b: Participants show higher physiological arousal during the reception of the torture video compared to the normal video.	Participants showed higher arousal (skin conductance) during the torture video. There were no differences with regard to heart rate.
	Participants reported more empathetic concern after the torture video.
	Participants were more likely to attribute feelings to the robot after the torture video.
Influence of Prior Interaction	
H2a: Prior interaction with the robot results in more negative feelings during the torture video.	Prior interaction had no effect.
H2b: Participants who interacted with the robot empathize more with the robot than participants who did not interact with the robot	Prior interaction had no effect.
H2c: Participants who interacted with the robot evaluate the torture video as more negative than participants who did not interact with the robot	Prior interaction had no effect. There was a marginal interaction effect with type of video.
H2d: Participants who interacted with the robot show stronger physiological responses than participants who did not interact with the robot.	Prior interaction had no effect.
Influence of Personality Traits	
H3: People will show stronger emotional reactions in self-report and physiological arousal when they (a) score high in their need to belong, (b) score high in their high affiliative tendency, (c) score high in loneliness, (d) are generally more empathic, and (e) are female.	No significant regression model emerged.

employing psychophysiological responses as well as self-report on emotions and empathy after watching a video in which a dinosaur robot was tortured.

In line with our hypothesis H1a, results show that the type of video influenced participants' subjective feelings, as they experienced more negative and less positive emotion after the reception of a video in which the robot was tortured compared to a video in which the robot was treated nicely. In addition, the skin conductance level was higher during the reception of the torture video, which confirms H1b. Moreover, participants reported more empathic concern (pity for the robot/angry at the torturer) after the torture video. Because "type of video" was a within-subject factor and people were able to directly compare the videos, it can be argued that these results might have been affected by demand characteristics or social desirability. However, since numerous studies show that people usually do not admit that they see robots or agents as social beings [79], it is still surprising that participants admitted to having negative feelings when an artificial animal is tortured. Moreover, the concern of demand characteristics does not apply for the differences found with regard to physiological arousal. Therefore, socially desirable behavior does not seem to be an appropriate explanation. Apparently, we react emotionally towards robots just as we also show social reactions in interactions with robots.

Based on the work of Meyer et al. [76], Groom et al. [47], and Bartneck and Hu [7], we argued that the acquaintance with the robot might influence the participants' experience of emotions during and after the reception of the video as well as the evaluation of the robot and the video itself (H2). Surprisingly, the prior interaction with the robot had no influence at all. There might have been two processes at work here, which canceled each other out and cannot be disentangled by means of our data. On the one hand, the interaction might have (a) led (some) people to recognize that Pleo is rather stupid, meaning that they would find it acceptable for Pleo to be destroyed (cf. [7]). On the other hand, (b) (some) people might have liked Pleo after the interaction, established an initial bond, and then felt sorry for Pleo. In consequence, the mean values upon which we are focusing here might give rise to the impression that the opportunity to interact with the robot does not have any effect at all, even though there are, in fact, opposing processes at work. With regard to Pleo's perceived intelligence, however, we can say that participants did not particularly perceive Pleo as stupid ($M = 3.12$ on a 6-point Likert scale). The lack of a significant effect of the prior interaction might therefore either indicate that prior interaction does indeed not make a difference, or that the time given for bonding was simply too short. At least we can state that participants who were unacquainted with the robot did not show significantly less emotional reaction, empathic concern or pity.

Within future studies, we therefore plan to include an instrument to measure the participants' subjective ratings of whether they established a bond with Pleo. Moreover, it would be interesting to include a control group which interacted more often with Pleo in order to determine whether repeated interactions have an impact on participants' feelings towards the robot.

Furthermore, our findings did not confirm that participants' need to belong, their affiliative tendency and their scores on loneliness are predictors of their physiological arousal or self-reported emotions after the video reception (H3a, b & c). Moreover, participants' general ability for empathy was not predictive of their emotional experiences. On the one hand, the absence of results for these concepts is surprising, because numerous studies show strong robust influences of the empathy trait on all kinds of emotional reactions (e.g. [37]) and as described above, people high in the need to belong are more sensitive to social cues and perform better in encoding them, which is part of the process of empathy [37]. One explanation is that our sample was quite homogeneous, with all of our participants scoring high in affiliative tendency, low on the loneliness scale, and high for all four empathy trait factors. Thus, there might not have been sufficient variance in our sample. Moreover, the post-hoc power analysis revealed that the power in our experiment was too low to find medium or small effects within our data set with a regression analysis with multiple predictors. The interplay of these factors should be investigated in more detail in a separate study with a more diverse and larger sample.

To summarize, we systematically investigated whether people react emotionally towards a robot and found that the participants in our study reported positive and negative emotions and empathic concern on different self-report measures based on the videos showing a friendly interaction with a robot or a robot being tortured. Moreover, they showed more negative emotions and more empathic concern when the robot is tortured, and they displayed increased physiological arousal. Presumably due to our homogeneous sample we did not find personality traits to be predictive for participants' emotional responses. Further research will hopefully provide more detailed insights into these processes.

Considering the enormous ongoing research efforts to build robot companions, we suggest that in addition to the development of these systems, more research should also focus on the investigation of the emotional effects of human-robot interaction. Because people can also experience negative emotions while interacting with a robot (see also [7, 8, 55]) or experience feelings of loss when the system is taken away [101], more knowledge is needed to avoid possible negative experiences, especially when developing systems for long-term interaction.

4.1 Limitations and Future Research

One limitation of the study is that we used videos in our experiment and that participants saw potentially fictional material. Perhaps reactions would have been different if the torture of Pleo had been performed live in front of the participants. Moreover, the robot's shape is also rather fictional as dinosaurs are not part of our daily experiences. Participants might react more strongly to a robot with a humanoid shape.

Moreover, we have used standardized instruments to measure emotional reactions. It is, however, more complicated to investigate empathic concern. Thus other study designs and other measures (e.g. behavioral observation, fMRI) might give more insight in whether people do not only experience emotional reactions, but also empathize with robots. Further, it would be interesting to see whether emotional reactions towards robots and empathy with robots refer to the same neural correlates as empathy for humans. In this respect, results from fMRI studies suggest that empathic reactions are not restricted to beloved persons and that "neural simulation of the pain of another person occurs independently of the affective link between the empathizer and the person in pain" ([49], p. 3). While these studies are based on stimulus material that solely includes humans, they could be extended by showing not only humans, but also robots in pain.

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