Social Facilitation with Social Robots?

Nina Riether
Research Institute for Cognition and Robotics
Bielefeld University, Germany
nriether@techfak.uni-bielefeld.de

Frank Hegel
CITEC Center of Excellence
Bielefeld University, Germany
fhegel@techfak.uni-bielefeld.de

Britta Wrede
Applied Informatics Group
Bielefeld University, Germany
bwrede@techfak.uni-bielefeld.de

Gernot Horstmann
Department of Psychology
Bielefeld University, Germany
gernot.horstmann@uni-bielefeld.de

ABSTRACT

Regarding the future usage of social robots in workplace scenarios, we addressed the question of potential mere robotic presence effects on human performance. Applying the experimental social facilitation paradigm in social robotics, we compared task performance of 106 participants on easy and complex cognitive and motoric tasks across three presence groups (alone vs. human present vs. robot present). Results revealed significant evidence for the predicted social facilitation effects for both human and robotic presence compared to an alone condition. Implications of these findings are discussed with regard to the consideration of the interaction of robotic presence and task difficulty in modeling robotic assistance systems.

Categories and Subject Descriptors

J.4 **[Social and Behavioral Sciences]:** Psychology

General Terms

Human Factors, Experimentation, Measurement, Theory

Keywords

Social facilitation, social robotics, HRI, mere presence

1. INTRODUCTION

Considering recent developments in the various domains contributing to social robotics, human-robot-interaction is going to take place in a growing number of areas of daily life in the future. Social robots are already giving support in specific tasks, like helping humans preserve energy [32,45], assisting as guides [42], tutoring children [20,27] or helping us lose weight [24] to just name a few. Hence, social human-robot-interaction becomes more and more likely to find its way into workplace scenarios as well, where robotic support might be highly useful, but where human performance is still of indispensable importance and should certainly not be impaired when humans and robots work shoulder to shoulder in cooperation.

Breaking down the effects of robotic support and assistance into the most basic building-blocks poses an urging, yet unanswered question: What effect does the mere presence of a robot have on human performance without further interaction or intervention in the current workflow?

HRI'12, March 5–8, 2012, Boston, Massachusetts, USA.

1.1 Theoretical Background and Related Work

Over the past decades, a bulk of research in social psychology has contributed to provide a deeper understanding of the influence of social presence on human performance. Among others, a well investigated approach is the so-called social facilitation paradigm. This effect is one of the oldest in social psychology and states that performance of an easy or well-learned task is facilitated in the presence of another person versus alone, whereas performance of a complex or new task is impaired in the presence of another individual. After the first description of this effect by Triplett [44] and later experimental investigations by Zajonc [50,51] and others [4,5,7-9,13,14,23,26,41,49], various explanatory theories evolved, which can be grouped into three categories (see Guerin [19]): drive-/ arousal-theories, social comparison theories and cognitive process theories.

Overall, none of them is able to account for all the specific results in the field of social facilitation research, however, all theories are able to roughly predict the same findings from the basic paradigm. An implication drawn by Guerin [19] and Aiello and Douthitt [1] is that these theories rather act together in a network of social responses next to social loafing, cooperation and competition. Social facilition does not seem to be a simple and basic element to social behavior, but rather a complex network of individual learning history, social standards and cognitive functions. Which explanatory model applies where and when seems to be substantially dependent on the specific situational characteristics.

Cognitive process theories concentrate on physical distraction [26], shared attention, attention conflict [23,41] and restricted focus of attention [14] as explanations for the social facilitation effects and basically play a more or less overt essential and/or additional role in all explanatory theories.

A second approach takes social comparisons into account. Experiencing concern about being evaluated, worry about ones performance considering social norms and standards, matching of actual and ideal behavior may result in the predicted effects [8,9,13]. In line with these evaluation apprehension and self-awareness theories go impression management approaches [4,7]. Berger et al. [5] also proposed inhibition of socially undesirable behavior in front of an observer, e.g. using rehearsal strategies, etc., as partial explanation of the social facilitation effects to occur. Different from the previous arousal theories, social comparison theories include a deliberate choice of socially acceptable behavior in order to meet specific situational requirements.

Zajonc used drive theory (Hull-Spence drive theory, [43]) to explain social facilitation effects, which proposes that the presence of others increases the individual drive or arousal level and thereby enhances the reaction potential for dominant responses. Dominant responses are correct and/or fast responses on easy or well-learned tasks and similarly incorrect, hence often slow responses on complex or new tasks. Thus, presence of others leads to an enhancement of simple task performance and to an impairment of performance on complex tasks.

Dashiell [10] already specified different forms of presence, the most basic being the mere presence of a non-engaging quiet spectator, and Zajonc [51] emphasized that although presence of an observer may also lead to a heightened evaluation potential, evaluation apprehension was not necessary for the effects to occur, but mere presence was sufficient for social facilitation. The source of heightened arousal could be enhanced alertness through the presence of a social being. Zajonc [51] already claimed social stimuli to be the most unpredictable. Unpredictability most likely leads to heightened alertness [37] and "hard-wired" monitoring-responses [30] (see [19] for extensive review), resulting in enhanced arousal compared to an alone-condition.

Taken together, all theories indicate that the perception of co-presence of another social being is necessary to elicit the predicted effects. The aim of the present study is to investigate whether a robot also generates co-presence and thus, whether the social facilitation effects can also be observed for robotic presence. This draws several implications for the use of robots as task companions, tutors, etc., because their presence might produce opposing effects dependent on the task criteria. Robotic presence might lead to an impairment of task performance when the task is new or complex, but also the mere presence of a robot might work as a motivator on easy or well-learned tasks. Differential effects of robotic presence on human task performance as a function of task difficulty are crucial for the development of robotic assistance systems, which aim at maximizing support and optimization of human performance. However, these effects are still poorly understood.

A couple of studies tried to shed light on the question whether social facilitation occurs in the presence of virtual agents, e.g. [40,46,52], but have lead to mixed results. Problems due to ceiling effects, difficulties with the dependent measures and methodology of the studies complicate the comparability to the human studies. As Krämer [25] noted, social facilitation research with virtual agents oftentimes cannot underline the effectiveness of the uniquely defined social facilitation paradigm. This is mainly due to an overall interpretation of performance variations as either social facilitation (in case of an enhancement) or social inhibition (in case of an impairment), without experimentally controlling for varying task difficulty.

To our knowledge, three studies build an exception to this by using sound experimental methodology. Hoyt, Blascovich and Swinth [22] replicated a previous human social facilitation study [6] with virtual agents and found evidence for social inhibition (performance impairment on difficult tasks) for virtual avatars. Zanbaka, Ulinski, Goolkasian and Hodges [53] investigated the social facilitation paradigm using a real human, a projected virtual human and a virtual human in an immersive environment and also revealed evidence for social inhibition on a mathematical task. Park and Catrambone [38] showed that for verbal, spatial and mathematical tasks a virtual agent was able to elicit the same social facilitation effects (enhancement on easy, impairment on complex tasks) versus an alone condition as a human confederate.

Regarding social robots, there exist hints to potentially comparable effects [3,48], however these studies have not examined the social facilitation paradigm using the precisely defined experimental methodology, e.g. no alone control group, no experimental control for or manipulation of task difficulty was used. The interpretation of potential performance variations thus remains ambiguous.

1.2 Hypotheses

Up until now, no study has yet investigated mere presence effects of a social robot on human performance using the experimental social facilitation paradigm. Our study aimed at filling this gap. Regarding comparable findings from the field of virtual agents, our main hypothesis was that the presence of a social robot as well as the presence of a human confederate should lead to the predicted performance variations.

The key findings in the social facilitation paradigm can also be expressed as a large performance difference between easy and complex tasks for presence conditions compared to a relatively smaller performance difference between easy and complex tasks for the alone (baseline) condition.

Following this rationale, we predicted (1) that both the presence of a robot as well as the presence of a human confederate should lead to an increase in performance differences compared to the alone condition. As a second, undirected hypothesis, we were interested (2) whether these effects significantly differed between the human confederate and the robot.

2. METHODS AND PROCEDURE

2.1 Participants and Design

106 right-handed students (78 women) with a mean age of 23.31 years (SD = 2.99) were recruited on campus of Bielefeld University and received either partial course credit or chocolate bars for their participation. They were randomly assigned to one of three groups that resulted from a 3 (*presence:* alone vs. human confederate present vs. robot present) x 2 (*task difficulty:* easy vs. complex) mixed-factorial design. Presence type served as between-subjects- and task difficulty served as within-subjects factor.

The performance on four computerized tasks of cognitive and motoric nature (anagram solving, numerical distance, finger tapping and motoric tracking), which were administered both in an easy and complex version, served as the dependent variables. The task-difficulty was validated in a previous rating study (see 2.2).

The study was approved by the Ethics Committee of Bielefeld University.

2.2 Performance Tasks

In the anagram solving task, which is a common task in social facilitation research [2,11,38], participants had to quickly and accurately solve 5-letter anagrams by rearranging the letters of each nonsense-word back into the correct order. To construct the two difficulty categories, the 10 anagrams with the fastest and the 10 anagrams with the slowest solution times were chosen out of a rating study with 112 different anagrams. The two difficulty conditions differed significantly ($t(9) = 6.47$, $p < .001$, *Cohen's* $d = 2.90$). In the current study, these 20 anagrams were separately presented in randomized order on the computer screen. The participants had to enter the correct solution via the computer keyboard. Reaction time (time from stimulus presentation until first keypress of the correctly solved anagram) and accuracy (ratio of correct solutions to total number of anagrams) served as dependent variables.

Regarding the numerical distance task, the numerical distance effect revealed by Moyer and Landauer [33] built the basis for the construction of easy and complex categories. It states that regarding the comparison of the numerical value of two digits, reaction time for this comparison is inversely proportional to the numerical distance between the two digits. That is, the larger the numerical distance between two digits, the faster and more accurate the responses concerning their comparison.

Here, participants were asked to decide by means of a keypress whether a presented number was bigger or smaller than 5. For the easy condition these numbers were either 1 or 9, for the complex condition 4 or 6. Both difficulty conditions consisted of 10 trials each. Easy and complex trials were presented in fully randomized order. A previous rating study showed a significant difference between these two categories of task difficulty ($t(7) = 4.43$, $p < .01$, $d = 0.75$). The dependent variable was response latency (time from stimulus presentation until keypress).

In the finger tapping task, participants had to tap a recurring key sequence on their keyboard as quickly and accurately as possible for 90 seconds. The key sequence, which was presented on the computer screen in front of them, consisted of 2 alternating keys in the easy condition ("S" and "L") and 6 alternating keys ("E", "K", "V", "A", "P", "X") in the complex condition. The order of the two difficulty conditions was chosen at random. According to the previous rating study, the two conditions (easy, complex) differed significantly from each other ($t(7) = 4.68$, $p < .001$, $d = 2.34$). The total number of taps served as the dependent variable.

For the motoric tracking task, participants had to use the computer mouse in order to follow an array of square buttons on their computer screen. The task was to click on a square box that appeared at a random position on the computer screen and as soon as that box was clicked, a second one appeared at another random location. One trial consisted of a sequence of 6 consecutive box presentations and 10 trials per difficulty category were run, resulting in 20 fully randomized trials total. To construct the two difficulty conditions, subjects were asked to either hold the mouse in their right hand (for the easy condition) or to hold it in their left hand (for the complex condition) before each trial. Additionally, the boxes in the easy conditions were four times larger than in the complex condition. The previous rating study revealed a significant difference between the two difficulty conditions ($t(7) = 13.20$, $p < .001$, $d = 6.09$). The overall solution time (time from onset of first box until offset of sixth box) per trial was measured as the dependent variable.

The order of the four tasks within the experiment was fixed and thus the same for all participants, starting with the finger tapping task, followed by the numerical distance task, the motoric tracking task and finally the anagram solving task. Carry-over effects were regarded as negligible since the task order was standardized over the three presence groups and the relevant comparisons for the analysis were between-groups and not between-tasks. Also, the different tasks aimed at diverse cognitive and motoric domains.

LiveCode (RunRev Ltd.) software was used for the development and conduction of the computerized tasks.

2.3 Presence Conditions

For the robotic presence condition, we used the anthropomorphic robot head Flobi, which has technically [29] and aesthetically [21] been designed at Bielefeld University. As one key feature, Flobi's robot head consists of exchangeable modular parts (e.g. facial features such as hairstyle, lips, eyebrows), which makes it possible to alter Flobi's appearance quickly and flexibly. Because the human confederate was female, we also chose a female version of Flobi for this study, also see Figure 1.

The behavior of the human confederate and the robot followed a previously defined time-based matching behavior script and in case of the robot was pre-programmed. To rule out potential emotional influence factors on the social facilitation effects, no emotions were displayed by the confederate or the robot during the experiment.

Thorough training, an additional study without a robot condition and previous behavior ratings ensured that the confederate was able to follow her strict behavior script and maintain the required facial expression. The robot as well as the female confederate were unknown to all participants.

Figure 1. Anthropomorphic robot head Flobi.

Upon entering the laboratory, both the robot and the human confederate glanced towards the participant and nodded slightly, then went back to their tasks. Over the course of the experiment, they glanced towards the participant every 3-4 minutes. In between, they looked at their computer screen, shortly glimpsed up at the room and changed their facial expression from a rather "neutral" to "concentrated" look back and forth several times.

2.4 Procedure

The experiment took place in a laboratory of the Department of Psychology at Bielefeld University. The acoustically shielded chamber (approximately 2.5 m x 3.5 m) contained a single desk which the participant either sat at alone or opposite to the human confederate or the robot, depending on the presence condition (see Figure 2).

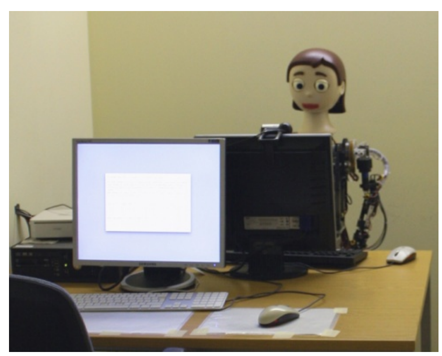

Figure 2. Laboratory set-up.

Upon arrival, participants were provided with information regarding the experimental procedure. It was explained to them that as part of a software evaluation they had to work on four different tasks on the computer and answer a questionnaire afterwards. In the presence conditions, the participants were also told that either a technical assistant or a robot was going to be sitting in the room with them to either monitor certain software parameters on their own computer screen or a specific visual task, respectively, which was explained as being part of a cooperative study with an informatics group. The important criterium here was that both the human confederate and the robot had an equally engaging visual task to perform on their own computer screen, which was positioned to the opposite of the participants' screen. Participants were then told not to communicate with the attendant during the experiment.

Next, the participants entered the laboratory, the experimenter started the experimental software and left the room. After completion of the performance tasks, participants were led to an adjacent room for the manipulation check form, that asked how observed they felt during the experiment, and debriefing.

3. RESULTS

Difference scores between the easy and complex conditions of the tasks were calculated for the three presence groups. A one-factorial ANOVA for the presence factor (alone vs. human confederate present vs. robot present) was computed to give an overview of any effects of presence. Planned comparisons were used to analyze relevant between-group contrasts - alone vs. both presence groups (one-sided), human confederate vs. robot (two-sided).

3.1 Anagram Solving

Concerning task accuracy, the ANOVA revealed significant differences between the presence groups ($F(2,103)=3.61$, $p < .05$, $\eta^2 = .07$). Planned comparisons further indicated significant differences between the alone-group and the two presence groups ($t(103)=1.91$, $p < .05$, $\eta^2 = .03$), showing a significantly larger difference score for the presence groups compared to the alone control group. The contrast between the human confederate and the robot was marginally significant ($t(103)=1.92$, $p = .057$, $\eta^2 = .03$), also see Table 1 and Figure 3.

As a result of the differences in the accuracy scores between the presence groups, we refrained from analyzing response latencies, because of the amount of missing reaction-time data especially in the complex condition.

Table 1. Anagram solving – Mean number of correct responses for easy and complex condition.

	Easy		Complex	
	M	*SD*	*M*	*SD*
Alone	9.71	0.57	6.26	2.91
Human present	9.80	0.41	5.91	2.75
Robot present	9.55	0.71	4.33	3.21

3.2 Numerical Distance

Regarding the response latencies of the numerical distance task, the median reaction times differed significantly between the presence groups ($F(2,103)=3.96$, $p < .05$, $\eta^2 = .07$), also see Table 2. The two presence groups showed a significantly larger difference score than the alone group ($t(103)=2.47$, $p < .01$, $\eta^2 = .06$), whereas the planned comparisons did not reveal a significant difference between human and robotic presence ($t(103)=1.30$, $p = .196$, $\eta^2 = .01$), see Figure 3 (note that even though the trend appears dissimilar to the other tasks, the difference between human und robot presence is not statistically significant and thus, the data follows the same pattern of post-hoc results as the other tasks).

Table 2. Numerical distance – Average median response latencies in milliseconds for easy and complex condition.

	Easy		Complex	
	M	*SD*	*M*	*SD*
Alone	561.21	166.22	579.08	163.00
Human present	527.80	89.62	599.11	142.41
Robot present	534.88	105.81	580.58	119.99

3.3 Finger Tapping

Regarding the finger tapping task, the ANOVA did not uncover a significant overall effect of presence ($F(2,103)=2.19$, $p = .117$, $\eta^2 = .04$), however, the planned comparisons indicated the same pattern as above. The contrast between the alone and the two presence groups revealed significantly larger difference scores for the presence groups compared to the alone group ($t(103)=1.88$, $p < .05$, $\eta^2 = .03$), also see Table 3 and Figure 3. No statistically significant difference was found between the presence of human confederate and the robot ($t(103)=0.96$, $p = .340$, $\eta^2 = .01$).

Table 3. Finger tapping – Mean number of taps total for easy and complex condition.

	Easy		Complex	
	M	*SD*	*M*	*SD*
Alone	325.74	189.57	172.50	73.54
Human present	341.46	154.59	143.74	48.68
Robot present	370.91	154.31	134.06	40.95

3.4 Motoric Tracking

For the motoric tracking task, no significant results could be obtained. Both ANOVA ($F(2,103)=0.88$, $p = .416$, $\eta^2 = .02$) and planned comparisons did not reveal any significant effects of presence (alone vs. presence: $t(103)=0.57$, $p = .29$, $\eta^2 = .00$), human vs. robotic presence: $t(103)=1.19$, $p = .24$, $\eta^2 = .01$), probably due to large within- and between-group-variances. This task will thus be excluded from further discussion.

3.5 Perception of Being Monitored

Concerning the subjective perception of having been monitored during the experiment, significant overall effects of presence could be obtained ($F(2,103)=6.35$, $p < .01$, $\eta^2 = .11$). Participants in the two presence conditions indicated significantly higher scores than participants in the alone-control-group ($t(103)=2.82$, $p < .01$, $\eta^2 = .07$).

Furthermore, the results revealed a significant difference between the presence of the human confederate and the robot ($t(103)=2.23$, $p < .05$, $\eta^2 = .05$). The highest scores were obtained in the robotic presence group ($M = 5.24$, $SD = 3.42$), followed by the human presence ($M = 3.51$, $SD = 2.81$) and the alone group ($M = 2.56$, $SD = 3.33$).

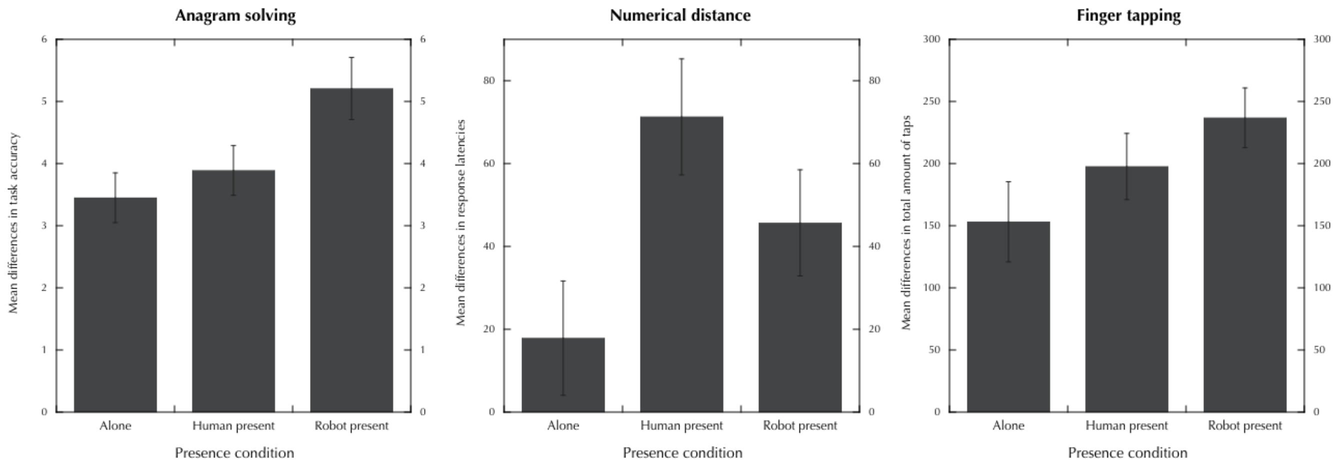

Figure 3. Mean differences between easy and complex condition for the three tasks (error bars show standard error of mean).

4. DISCUSSION

The present study investigated whether mere robotic presence would lead to social facilitation effects comparable to human presence. Therefore, an experiment was conducted that manipulated type of presence (human confederate present, robot present, alone-condition) and task difficulty (easy, complex) on four different motoric and cognitive tasks.

Overall, the present results replicated the social facilitation effect both for human and robotic presence. The key hypothesis (1) was supported: performance differences between easy and complex tasks were significantly higher both for the human confederate as well as the robot in comparison to the baseline of the alone condition. The results prove that mere presence of a social robot indeed leads to similar performance effects as human presence. Based on these findings, implications for subsequent research in the fields of social cognition, social psychology, human-robot-interaction and anthropomorphism will be addressed below.

Furthermore, subjective perception of having been monitored also differed significantly between the alone and presence conditions, and additionally between the human and robot condition, robotic presence eliciting the strongest observation impression followed by presence of the human confederate and the alone condition, respectively. Taken together, these subjective results match the objective findings, indicating that the presence conditions indeed generated a perception of co-presence. Additionally considering the strongest observation impression elicited by robotic presence, this also matches the descriptive findings of the anagram and tapping task for the complex condition, where robotic presence lead to even stronger performance impairments than the presence of the human confederate.

The higher observation impression scores for the robot condition compared to the human confederate might be due to surveillance and novelty effects. The cameras in the robot's eyes might have led to an increased observation impression, because they leave room for the assumption that someone else might also be watching through the robot's eyes. Regarding novelty effects, none of the participants in the robot group reported previous interaction with a robot. Because of this unfamiliarity, the robotic presence might have been potentially more distracting than the rather familiar presence of another human individual. It might thus be enlightening for future research to further examine the role of familiarity in this paradigm by means of a previous interaction with the robot. If the current findings could simply be reduced to a novelty effect of robotic presence, then the robot condition should either not differ at all from the results of the human confederate or lie below, but not above them, as it was the case here for the subjective data and descriptive results of the tapping and anagram task.

A similar perspective can be assigned to a presumably higher unpredictability of the robot compared to a human individual considering first-time interaction. Participants had no prior knowledge of the potential range of behavior that the robot might exhibit or how sophisticated its "cognitions" might be. Since robots do not play regular parts in our everyday lives yet, functionality ascriptions are prone to differ largely between users and to a great degree are based on the robot's appearance [12]. That is, unpredictability seems to be a likely influencing factor for the current findings but also for human-robot-interaction in general. Recent studies suggest unpredictability as a mediator of anthropomorphism in human-robot-interaction [15,47], an unpredictable robot leading to higher ascriptions of anthropomorphism. As Epley, Waytz and Cacioppo [16] put it, anthropomorphism "provides an intuitive and readily accessible method for reducing uncertainty in contexts in which alternative nonanthropomorphic models of agency do not exist." p.871

Gardner and Knowles [18] describe the social facilitation paradigm as a unique behavioral measure of perceived co-presence for the research on anthropomorphism, alluding to the profoundness of "human-like" representation.

Taken together, unpredictability might also account for the present findings in the robot condition, further considering the effects of unpredictability itself on arousal (see above).

Previous interaction with the robot would allow participants to generate an adjusted mental model of the robot's true functionality and behavior range. Future studies might examine whether the robot in return loses parts of its impact on the social facilitation effects in comparison to a human confederate.

To further clarify the influence of social agency effects [28,31,39] and especially a potential confounding with novelty/unfamiliarity effects on the current findings in the robot condition, it appears helpful to integrate a condition in the paradigm with a robot that is obviously switched-off in a future study.

Similarly, length of presence and/or repeated presence should be taken into the scope of further investigation, especially since temporal dimensions haven't been elaborately examined yet in social facilitation theory. Drive explanations would foresee a reduction of social facilitation effects over time, whereas social comparison explanations might predict a gradual increase of the effects because of potentially enhanced self-monitoring.

It certainly seems relevant to also focus on individual characteristics and dispositional factors in further research. Aiello and Svec [2] report individual locus of control to affect perception of and reaction to performance situations. Test and social anxiety might reasonably influence social facilitation effects in a similar manner through differential reaction to performance situations. Similarly, dispositional influence factors for human-robot-interaction should also be taken into account. Negative attitudes towards robots or robot anxiety [34,35,36] might likely represent potential moderating factors. Furthermore, Eyssel and Kuchenbrandt [17] as well as Waytz, et al. [47] demonstrate differential effects of "desire to control" on anthropomorphism in human-robot-interaction.

How would social facilitation theory explain the current results? Considering a unified and interactive perspective on social facilitation theory, according to drive aspects, robotic and human presence equally elevated participants' arousal levels, which in turn caused the current performance differences. Cognitive process components would emphasize distraction and attentional conflicts in the two presence conditions for the current findings. Social comparison aspects would make evaluation apprehension and impression management elicited by the human confederate and the robot accountable for the found effects. That is, participants experienced concern about how the robot or human confederate would evaluate them (which might in turn lead to heightened arousal and distraction).

Further research on potential boundary conditions of social facilitation theory is needed to distinguish potential influence factors like familiarity, role ascription and duration of presence in order to draw sound conclusions for and comparisons with robotic presence. It still remains subject to elaborate investigation in the fields of social agency and anthropomorphism why and to what extent people respond socially to non-human entities, but our findings contribute to these topics of research by indicating that the mere presence of a social robot is able to elicit a perception of co-presence. A mere presence design represents the most conservative way of studying the social facilitation paradigm, allowing high standardization and elimination of potential confounding effects of role ascription, display of emotions, valence, etc. However, in line with [1,10], we propose the social facilitation effects to further be enhanced by extending the behavior of the confederate and the robot to other roles than that of a quiet, non-enganging spectator. Together with further social interaction, explicit motivation, evaluation and feedback, these issues build consequential research questions for further application of the present findings.

An implication from the current results for the design of robotic systems is that social facilitation effects should be taken into account for the development of robotic platforms in workplace, tutoring or other assistance scenarios. Robotic presence, as human presence, may impair performance, especially when a task is new or difficult. An omnipresent robotic assistence system, which is active throughout all human working steps, may therefore not be necessarily advisable and even counterproductive. Conversely, robots may have a motivating effect just by being present in the same room as the participant when an easy or well-learned task has to be performed. Every decision of presenting a robot should thus be a thoughtful one and include sound theoretically driven considerations of other potential influence factors partially discussed above.

As social robots will continue to find their ways into our everyday lives, the necessity of psychologically-founded exploration of effects of social presence will equally continue to grow and become more fine-grained. Aside from this, new opportunities for investigating the boundary conditions of social cognition may arise from the exploration of social responses to non-human entities and future research might fruitfully address them.

5. ACKNOWLEDGEMENTS

We gratefully acknowledge partial support by the German Aerospace Center (DLR) with funds from the Federal Ministry of Economics and Technology (BMBF) due to resolution 50RA1023 of the German Bundestag.

The authors would like to thank Florian Berner for developing and implementing the robot software, and also Iris Franzke, Karola Hueppmeier, Melissa Preusse, Iris Sossalla and Hendrik Stellmacher for their support in conducting the study.

6. REFERENCES

[1] Aiello, J.R. and Douthitt, E.A. 2001. Social facilitation from Triplett to electronic performance monitoring. *Group Dynamics: Theory, Research, and Practice*. 5, 163–180.

[2] Aiello, J.R. and Svec, C.M. 1993. Computer Monitoring of Work Performance: Extending the Social Facilitation Framework to Electronic Presence. *Journal of Applied Social Psychology*. 23, 537–548.

[3] Bartneck, C. 2003. Interacting with an embodied emotional character. *DPPI 2003*. 55-60.

[4] Baumeister, R.F. 1982. A self-presentational view of social phenomena. *Psychological Bulletin*. 91, 3–26.

[5] Berger, S.M., Hampton, K.L., Carli, L.L., Grandmaison, P.S., Sadow, J.S., Donath, C.H. and Herschlag, L.R. 1981. Audience-induced inhibition of overt practice during learning. *Journal of Personality and Social Psychology*. 40, 479–491.

[6] Blascovich, J., Mendes, W.B., Hunter, S.B. and Salomon, K. 1999. Social "facilitation" as challenge and threat. *Journal of Personality and Social Psychology*. 77, 68–77.

[7] Bond, C.F. 1982. Social facilitation: A self-presentational view. *Journal of Personality and Social Psychology*. 42, 1042–1050.

[8] Carver, C.S. and Scheier, M.F. 1978. Self-focusing effects of dispositional self-consciousness, mirror presence, and audience presence. *Journal of Personality and Social Psychology*. 36, 324–332.

[9] Cottrell, N.B. 1972. Social facilitation. *Experimental social psychology*. In C.G. McClintock, Ed. Experimental social psychology. 185–236.

[10] Dashiell, J.F. 1930. An experimental analysis of some group effects. *Journal of Abnormal and Social Psychology*. 25, 190–199.

[11] Davidson, R. and Henderson, R. 2000. Electronic Performance Monitoring: A Laboratory Investigation of the Influence of Monitoring and Difficulty on Task Performance, Mood State, and Self□Reported Stress Levels. *Journal of Applied Social Psychology*. 30, 906–920.

[12] Duffy, B.R. 2003. Anthropomorphism and the social robot. *Robotics and Autonomous Systems*. 42, 177–190.

[13] Duval, S. and Wicklund, R.A. 1972. *A theory of objective self awareness*. New York: Academic Press.

[14] Easterbrook, J.A. 1959. The effect of emotion on cue utilization and the organization of behavior. *Psychological Review*. 66, 183–201.

[15] Epley, N., Akalis, S., Waytz, A. and Cacioppo, J. 2008. Creating social connection through inferential reproduction. *Psychological Science*. 19, 114-120.

[16] Epley, N., Waytz, A. and Cacioppo, J.T. 2007. On seeing human: A three-factor theory of anthropomorphism. *Psychological Review*. 114, 864–886.

[17] Eyssel, F. and Kuchenbrandt, D. 2011. Manipulating anthropomorphic inferences about NAO: The role of situational and dispositional aspects of effectance motivation. *RO-MAN 2011, IEEE International Symposium on Robot and Human Interactive Communication*. 467–472.

[18] Gardner, W.L. and Knowles, M.L. 2008. Love Makes You Real: Favorite Television Characters Are Perceived as “Real” in a Social Facilitation Paradigm. *Social Cognition*. 26, 156–168.

[19] Guérin, B. 1993. *Social facilitation*. Cambridge: Cambridge University Press.

[20] Han, J., Jo, M., Jones, V. and Jo, J.H. 2008. Comparative study on the educational use of home robots for children. *Journal of Information Processing Systems*. 4, 159–168.

[21] Hegel, F., Eyssel, F. and Wrede, B. 2010. The social robot “Flobi”: Key concepts of industrial design. *RO-MAN 2010, IEEE International Symposium in Robot and Human Interactive Communication.* 107–112.

[22] Hoyt, C.L., Blascovich, J. and Swinth, K.R. 2003. Social Inhibition in Immersive Virtual Environments. *Presence: Teleoperators & Virtual Environments*. 12, 183–195.

[23] Jones, E.E. and Gerard, H.B. 1967. *Foundations of Social Psychology*. New York: Wiley.

[24] Kidd, C.D. and Breazeal, C. 2008. Robots at home: Understanding long-term human-robot interaction. *IROS 2008, IEEE/RSJ International Conference on Intelligent Robots and Systems*. 3230–3235.

[25] Krämer, N.C. 2008. *Soziale Wirkungen virtueller Helfer*. Stuttgart: Kohlhammer.

[26] Kushnir, T. and Duncan, K.D. 1978. An analysis of social facilitation effects in terms of signal detection theory. *Psychological Record*. 28, 535–541.

[27] Lee, S., Noh, H., Lee, J., Lee, K., Lee, G.G., Sagong, S. and Kim, M. 2011. On the effectiveness of Robot-Assisted Language Learning. *ReCALL*. 23, 25-58.

[28] Louwerse, M.M., Graesser, A.C., Lu, S. and Mitchell, H.H. 2005. Social cues in animated conversational agents. *Applied Cognitive Psychology*. 19, 693–704.

[29] Lütkebohle, I., Hegel, F., Schulz, S., Hackel, M., Wrede, B., Wachsmuth, S. and Sagerer, G. 2010. The bielefeld anthropomorphic robot head “Flobi.” *ICRA 2010, IEEE International Conference on Robotics and Automation*. 3384–3391.

[30] Lynn, R. 1966. *Attention, arousal and the orientation reaction*. London: Pergamon.

[31] Mayer, R.E., Sobko, K. and Mautone, P.D. 2003. Social cues in multimedia learning: Role of speaker's voice. *Journal of Educational Psychology*. 95, 419–425.

[32] Midden, C. and Ham, J. 2009. Using negative and positive social feedback from a robotic agent to save energy. *Persuasive 2009, International Conference on Persuasive Technology*.

[33] Moyer, R.S. and Landauer, T.K. 1967. Time required for judgements of numerical inequality. *Nature*. 215, 1519–1520.

[34] Nomura, T., Kanda, T. and Suzuki, T. 2006. Experimental investigation into influence of negative attitudes toward robots on human–robot interaction. *AI & SOCIETY*. 20, 138–150.

[35] Nomura, T., Kanda, T., Suzuki, T. and Kato, K. 2004. Psychology in human-robot communication: An attempt through investigation of negative attitudes and anxiety toward robots. *ROMAN 2004, IEEE International Workshop on Robot and Human Interactive Communication*. 35–40.

[36] Nomura, T., Kanda, T., Suzuki, T. and Kato, K. 2008. Prediction of Human Behavior in Human-Robot Interaction Using Psychological Scales for Anxiety and Negative Attitudes Toward Robots. *Transactions on Robotics*. 24, 442–451.

[37] Norman, D.A. 1980. Twelve issues for cognitive science. *Cognitive Science*. 4, 1–32.

[38] Park, S. and Catrambone, R. 2007. Social facilitation effects of virtual humans. *Human Factors*. 49, 1054–1060.

[39] Reeves, B. and Nass, C. 2002. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. Cambridge: Cambridge University Press.

[40] Rickenberg, R. and Reeves, B. 2000. The effects of animated characters on anxiety, task performance, and evaluations of user interfaces. *CHI 2000, SIGCHI Conference on Human Factors in Computing Systems*. 49–56.

[41] Sanders, G.S. and Baron, R.S. 1975. The motivating effects of distraction on task performance. *Journal of Personality and Social Psychology*. 32, 956–963.

[42] Shiomi, M., Kanda, T., Ishiguro, H. and Hagita, N. 2007. Interactive Humanoid Robots for a Science Museum. *Intelligent Systems*. 22, 25–32.

[43] Spence, K.W. 1956. *Behavior theory and conditioning*. New Haven: Yale University Press.

[44] Triplett, N. 1898. The Dynamogenic Factors in Pacemaking and Competition. *American Journal of Psychology*. 9, 507–533.

[45] Vossen, S., Ham, J. and Midden, C. 2009. Social influence of a persuasive agent: the role of agent embodiment and evaluative feedback. *Persuasive 2009, International Conference on Persuasive Technology*.

[46] Walker, J.H., Sproull, L. and Subramani, R. 1994. Using a human face in an interface. *CHI 1994, SIGCHI Conference on Human Factors in Computing Systems.* 85–91.

[47] Waytz, A., Morewedge, C.K., Epley, N., Monteleone, G., Gao, J.-H. and Cacioppo, J.T. 2010. Making sense by making sentient: effectance motivation increases anthropomorphism. *Journal of Personality and Social Psychology*. 99, 410–435.

[48] Woods, S., Dautenhahn, K. and Kaouri, C. 2005. Is someone watching me? - consideration of social facilitation effects in human-robot interaction experiments. *CIRA 2005, IEEE International Symposium on Computational Intelligence in Robotics and Automation.* 53–60.

[49] Zajonc, R.B., Heingartner, A. and Herman, E.M. 1969. Social enhancement and impairment of performance in the cockroach. *Journal of Personality and Social Psychology*. 13, 83–92.

[50] Zajonc, R.B. 1965. Social facilitation. *Science*. 149, 269–274.

[51] Zajonc, R.B. 1980. Compresence. *Psychology of group influence*. In P.B. Paulus, Ed. Psychology of group influence. 35–60.

[52] Zanbaka, C., Ulinski, A., Goolkasian, P. and Hodges, L.F. 2004. Effects of virtual human presence on task performance. *ICAT 2004, International Conference on Artificial Reality and Telexistence.* 174–181.

[53] Zanbaka, C., Ulinski, A., Goolkasian, P. and Hodges, L.F. 2007. Social responses to virtual humans: Implications for future interface design. *CHI 2007.* 1561–1570.