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Learning with Educational Companion Robots? Toward Attitudes on Education Robots, Predictors of Attitudes, and Application Potentials for Education Robots

Natalia Reich-Stiebert[1] · **Friederike Eyssel**[2]

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Abstract Previous research on attitudes toward robots has emphasized the aspect of cultural differences regarding the acceptance of social robots in everyday life. Existing work has also focused on the importance of various other factors (e.g., demographic variables, interest in science and technology, prior robot experience) that predict robot acceptance. Specific robot types like service or healthcare robots have also been investigated. Nevertheless, more research is needed to substantiate the empirical evidence on the role of culture, robot type, and other predictors when researching attitudes toward robots. We did so by conducting a survey on attitudes toward education robots in the German context. Besides, in the present research, we investigated predictors of attitudes toward education robots. Contrary to previous findings, our results suggest that German respondents have neutral attitudes toward education robots. However, our data support the notion of relative reluctance to engage in learning processes that include robots. Regarding demographic variables and personality dispositions, our results show that gender, age, need for cognition , and technology commitment significantly predicted people's attitudes. Concerning potential areas of application, respondents could picture using education robots in domains related to science, technology, engineering, and mathematics and rejected education robots in fields of arts and social sciences.

✉ Natalia Reich-Stiebert
nreich@cit-ec.uni-bielefeld.de

Friederike Eyssel
fae5@nyu.edu

[1] Cluster of Excellence Cognitive Interaction Technology, Bielefeld University, Inspiration 1, 33619 Bielefeld, Germany

[2] New York University Abu Dhabi, P. O. Box 129188, Abu Dhabi, United Arab Emirates

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1 Introduction

The proliferation of technology shapes todays school and classroom activities. Projectors, laptops or smart boards have become quite common in education. Students and educators face the challenge of incorporating the most recent technological developments into learning and teaching processes. Latest advances in the field of educational technologies try to integrate robotic companions into learning contexts. For instance, the humanoid robot NAO is already used in several countries to support learning in computer and science classes, reaching from primary school to university courses [1]. With respect to this progress, questions arise concerning people's attitudes toward learning with the latest technological innovations. Will people accept education robots to support their learning? What are the preferred learning domains for education robots and under which conditions will people learn with an education robot? Do people's attitudes toward education robots vary dependent on interindividual differences and do cultural differences exist across countries? In order to investigate these questions, in the present research we explore attitudes toward education robots among a German sample. Previous research has shown that predominantly positive attitudes toward robots in general prevail in Germany [2]. Furthermore, results have indicated that Germans report a relatively positive opinion toward service robots in domestic environments [3] and assistive robots in the context of nursing homes [4]. However, so far, education robots have been under-researched in the German context even though education robots become more and more important as mentioned above.

In light of the fact that in the near future robots could also become part of various educational settings in Germany and throughout Europe, it may prove fruitful to explore attitudes toward robots that serve the purpose of supporting teachers as assistants to facilitate various learning activities.

Consequently, we investigated attitudes toward education robots as well as contact intentions that reflect people's interest to engage in learning processes with education robots among a German sample. Further, we explored predictors of people's attitudes and which applications people prefer for education robots in learning environments (e.g., domain preferences, robotic role in learning scenarios).

2 Related Work

2.1 Attitudes Toward Robots in Germany

Until now, few studies have investigated the acceptance of robots in various social sectors among German people, e.g., the acceptance of robots in general [2], the acceptance of service robots in domestic environments [3], the acceptance of assistive robots in healthcare [4].

For example, research on attitudes toward robots in general assessed people's opinion among EU citizens [2]. The survey gauged public perceptions, acceptance levels, worries and reservations. Most importantly, results indicate that the major part of German citizens report positive attitudes toward robots in general (69 %). Considering the application of robots, German respondents preferred robots in manufacturing, space exploration, and military and rescue. In education and leisure settings, however, robots were largely rejected.

Reich and Eyssel [3] have investigated the acceptance of service robots in domestic settings in a heterogeneous German sample. Overall, results showed that German people hold relatively positive attitudes toward service robots used in domestic environments. Yet, responses were not uniformly positive because participants also reported hesitation regarding the prospect of interacting with service robots and were not very eager to use them in their home.

In a survey on attitudes toward service robots in elderly care, Meyer [4] showed that just over half of the seniors and nursing staff reported positive attitudes. Nevertheless, about 40 % of the elderly participants rejected service robots in their daily life.

2.2 Predictors of Robot Acceptance

The existing literature also suggests predictors of attitudes toward robots in various fields [2,3,5–9].

For instance, in addition to the above-mentioned results from the Eurobarometer survey [2], results have indicated differences regarding demographic variables and interest in science and technology. Male participants held more positive attitudes (76 %) than female participants (65 %), and with regard to occupations, managers were more positive toward robots (82 %) than persons who looked after the home (57 %). Concerning age and education, the proportion of respondents with a positive attitude decreased with age, whereas the share of respondents with a positive attitude on robots increased, the higher the respondents' level of education. Additionally, a positive relationship between interest in science and technology and positive attitudes was found.

Bartneck et al. [5] also examined the influence of previous experiences with a social robot on respondents' attitudes toward robots in general. Participants with prior experience with a social robot reported higher positive attitudes toward robots indicating a positive impact of prior robot experience on robot acceptance.

Previous research has indicated that dispositional personality characteristics (need for cognition, desire for control, and dispositional loneliness) that are related to the concept of anthropomorphism, which is the tendency to attribute humanlike characteristics, emotions, and intentions to non-human agents [10], affect how people perceive technological gadgets and robots [11–13]. In order to apply these findings to service robots, Reich and Eyssel [3] investigated the influence of dispositional personality characteristics on attitudes toward service robots among the above-described factors. In addition to demographic variables (e.g., gender, occupation) and interest in science and technology, personality characteristics indeed predicted attitudes toward service robots: Male respondents were more positive toward service robots than female respondents and participants working in social careers reported less positive attitudes than participants working in non-social domains. Moreover, they found that interest in science and technology affected respondents' attitudes toward service robots positively. Interestingly, prior robot experience was no significant predictor of attitudes toward service robots. Regarding personality characteristics, a significant impact of need for cognition (NFC), that reflects the amount to which people engage in effortful cognitive activities [14], and dispositional loneliness was found. Participants high in NFC formed a more positive attitude toward service robots as compared to respondents low in NFC. Finally, results showed that dispositionally lonely participants were more positive toward service robots than socially connected respondents.

2.3 Attitudes Toward Education Robots

With regard to education robots, only few studies have examined people's attitudes toward education robots from a European perspective [15–17], but several studies have investigated this issue in East Asia (e.g., [18–21]).

To illustrate findings on the acceptance of education robots from the Asian context, Shin and Kim [18] have interviewed

Korean elementary, middle and high school students regarding their perceptions and attitudes toward learning about, from, and with robots. With respect to the aspect of learning *about* robots, respondents believed that robots would be an essential part of future society and thus, they reported that it would be important to learn how to use robots. In contrast, participants were skeptical when it came to learning *from* education robots. Whereas part of the participants were convinced that they could learn from robots because they deemed robots to make fewer mistakes and to be more intelligent than human teachers, other respondents were concerned about the robot teachers' lack in emotions and their inability to build warm relationships with students. Finally, regarding learning *with* education robots, a similar pattern was observed: Some respondents found the idea interesting and believed that robots could enhance their learning. On the other hand, participants expressed negative attitudes toward learning with education robots and reported discomfort because they were allegedly afraid of being observed by a robot.

In an interview study, Lin et al. [19] have explored general perceptions of robots, robot roles in the classroom, and favorite robot appearances among fifth-graders in Taiwan. Overall, the results have shown that the majority of the children had positive attitudes on robots in general. Similarly, they reported positive attitudes toward the idea of deploying robots in the classroom, and this prospect was perceived as useful and interesting. Nevertheless, clearly, some children feared that robots might distract them from learning and preferred traditional learning settings. With respect to robot appearance, most children preferred pet- or cartoon-like robots to humanoid robots.

Lee et al. [20] have surveyed attitudes toward intelligent education robots among teachers, students and parents in Korea. Whereas respondents had a positive attitude toward the use of robots in schools, they rejected the idea of using robots as teachers. Not surprisingly, teachers themselves were relatively critical of using robots as assistive technology in schools because they were concerned about being replaced by robots.

Liu [21] has investigated attitudes on educational robots and learning of robotics in Taiwan. Early adolescents with prior experience in learning about robotics and using robots participated in the interview study. The results have indicated that the respondents tended to perceive educational robots as a plaything that could be used for entertainment. Regarding learning of robotics, participants also reckoned learning of robotics as a way to high technology that contributes to the advancement of society. In addition, students considered learning of robotics as a source of employment.

Importantly, Choi et al. [15] have taken the European perspective into account in that these authors have investigated the acceptance of educational robots among Spanish and Korean parents. Results have shown that Spanish parents held a rather negative attitude toward educational robots and tended to see robots as 'machines', whereas Korean parents regarded educational robots as 'friends for their children'.

Another cross-cultural study has focused on the acceptance of tutoring robots in education among Korean, Japanese, and Spanish respondents [16]. Han and colleagues revealed similar results, with Spanish parents objecting to tutoring robots and toward purchasing tutoring robots than Korean and Japanese parents. Generally, Korean parents were most liberal and less reluctant toward the prospect of educating their children using tutoring robots. Han et al. attribute these findings to the fact that e-Learning is widely used in Korea and robotic learning (r-Learning) has become more popular in the Korean education context recently.

A recent study investigated teachers' attitudes on the use of tutoring robots in the classroom [17]. Eight teachers from four different European countries (England, Portugal, Scotland, and Sweden) were interviewed on their attitude on the integration of educational robots in the school and their concerns about the robots. Most importantly, teachers recognized the utility of robots that reduce their workload. They further preferred tutoring robots for group learning settings, as they perceived it more difficult to manage individual learning episodes in bigger groups of students. Additionally, teachers pointed out that tutoring robots could be used as a database to document information about the students' progress. On the other hand, teachers feared that tutoring robots might disrupt classroom activities. Besides, they were concerned about the administrative workload when they have to manage the access to the robot. Finally, teachers were worried about the robots' robustness when used with children.

2.4 Current Study

The studies presented thus far provide evidence that attitudes toward education robots are well researched in East Asia indicating ambiguous outcomes with respect to attitudes toward learning with education robots. The majority of the respondents reported positive attitudes toward education robots whereas some participants were concerned that education robots could have a bad influence on children's learning or could replace teachers. In contrast, only little research has been conducted in the European context suggesting that people hold rather negative attitudes toward education robots. Importantly, research findings have shown that European teachers were concerned about the resulting workload that is linked with the use of education robots.

Nevertheless, the existing body of research on attitudes toward education robots and predictors of education robot acceptance falls short of several specific aspects which we aim to address in the present research: For one, so far, most of the studies have been conducted in East Asia and little empirical data has been gathered in Europe. Although some studies have already investigated attitudes toward social robots in Germany, e.g., service robots for use in domestic settings [3] or healthcare robots for use in nursing contexts [4], there has been no systematic empirical approach to examine perceptions of education robots in Germany yet.

The use of robots in school and other learning scenarios might bring opportunities but also problems. When investigating students' attitudes on educational robots and their use for learning we can learn about people's expectations and reservations toward this new technology. The knowledge generated by this research can provide important information for robotics which cultural, situational or interindividual factors should be taken into account when using robots for educational purposes. Finally, especially in light of the previous mentioned aspects, existing research has neglected the impact of demographics, technology commitment, and personality characteristics on attitudes toward education robots.

With the present study, we therefore address these gaps in literature: The current research investigates attitudes toward education robots among a German sample in order to first, capture attitudes toward education robots among another European country, and second, examine German people's attitudes toward another specific type of social robots, namely education robots. Third, to address the lack of investigation of predictors on attitudes toward education robots, we explored the role of demographic variables (gender, age, education, and occupation), prior robot experience, NFC, and technology commitment. Fourth, we assessed respondents' view regarding the preferred applicability of educational robots in the learning context (e.g., school domain preferences, preferred robotic role in learning scenarios)—an aspect that has not been evaluated until now.

3 Method

To assess attitudes and predictors of attitudes toward education robots, we conducted an online survey with SoSciSurvey between March and May 2014. Participants were recruited via electronic bulletin boards and social networking services.

3.1 Hypotheses

We replicated and extended the existing literature by taking into account the following variables: demographic variables, prior robot experience, NFC, and technology commitment. The following hypotheses were tested:

H1 As gender effects have been observed in other studies on attitudes toward robots [2,3,7,8], we predicted that female participants would report higher negative attitudes toward education robots, higher education robot anxiety, and fewer contact intentions than male respondents.

H2 According to findings by the Eurobarometer survey [2] and Kuo et al. [7], we hypothesized that age would be a positive predictor of negative attitudes toward education robots and education robot anxiety, whereas contact intentions would be negatively predicted by age.

H3 We expected that level of education would negatively predict negative attitudes toward education robots and education robot anxiety, while contact intentions would be positively predicted by level of education following results derived from the Eurobarometer survey [2].

H4 In line with Reich and Eyssel [3] and the Eurobarometer survey [2], we expected that respondents with social occupations would be more negative and anxious toward education robots than respondents who work in non-social domains. Besides, participants working in social domains should report lower contact intentions to education robots.

H5 We predicted, in line with Reich and Eyssel [3], that the effect of prior robot experience on negative attitudes, education robot anxiety, and contact intentions should disappear when it is simultaneously investigated with technology commitment.

H6 We argue that NFC would be a negative predictor of negative attitudes toward education robots and education robot anxiety. Correspondingly, NFC should positively predict contact intentions to education robots, as suggested by Reich and Eyssel [3].

H7 We expected that technology commitment would be a negative predictor of negative attitudes toward education robots and education robot anxiety. Analogously, technology commitment should positively predict contact intentions to education robots. This hypothesis is based on findings from other studies on the positive impact of technology commitment on attitudes toward robots [2,3,5,8].

3.2 Participants and Procedure

$N = 345$ German respondents volunteered to participate in the online survey. First, participants had to report demographic information (gender, age, education, and occupation). To provide an idea about education robots, we then briefly described possible features and functions of such type of robots. We used a written description instead of using picture materials of already applied educational robots like NAO [22] or Engkey [23] in this introduction to circumvent that participants would merely provide responses regarding a *specific* type of education robot. Moreover, research on robot appearance revealed that people have individual preferences of how a robot should look like and in turn, the robot appearance leads to distinctive perceptions of it (e.g., [24,25]). Thus, to rule out undesired impacts on participants' attitudes due to the robots' appearance, we provided subjects with a written description. Participants received the following information about education robots:

Education robots can be used as assistants to teachers in the classroom and can help to arrange school lessons. Further, an education robot can serve as a personal tutor that helps you to edit a task or to promote your individual learning process. In the following areas an education robot can assist: An education robot can, for example, provide information on specific topics, query learned lessons, give advice to the learning process, correct errors, or provide feedback on your progress.

Subsequently, participants reported attitudes toward education robots, education robot anxiety, and contact intentions. Moreover, we assessed which application potentials (e.g., school domain, robotic role during learning processes) participants envisage for education robots in learning environments. Finally, after evaluating participants' attitude toward education robots, prior robot experience, NFC, and technology commitment were measured.

3.3 Measures

To collect participants' responses, we used 7-point Likert scales ranging from 1 (*not at all*) to 7 (*very much*). Items were recoded where necessary, with higher values indicating stronger endorsement of the respective construct.

3.3.1 Attitudes Toward Education Robots

In order to assess attitudes toward education robots, we used three different measures.

First, we asked participants to what extent they hold negative attitudes toward education robots (*Negative Attitudes toward Education Robots*). Therefore, we administered the *Negative Attitudes toward Robots Scale* (NARS; [26]) and adapted it by replacing the term 'robot' with the specification 'education robot'. Further, we modified the scale by adapting it to the educational context. For instance, the item "I feel that in future society will be dominated by robots" was adjusted to "I feel that in future school classes will be dominated by education robots". More example items read: "I would feel relaxed talking with education robots" or "I am concerned that education robots would be a bad influence on children". Items were reverse-scored where appropriate to build an index of negative attitudes toward education robots, with higher values indicating higher approval of negative attitudes toward education robots.

Second, we measured respondents' anxiety toward education robots (*Education Robot Anxiety*) by adapting the 11-item *Robot Anxiety Scale* (RAS; [27]) to the educational context. For example, the RAS item "I am concerned about what speed robots will move at" was amended to "I am concerned that education robots could be to fast for my individual learning pace". Participants further completed items such as: "I may be unable to understand education robots' utterances to me" or "Education robots may be unable to understand complex stories".

Third, in order to assess people's willingness for future learning with education robots, we developed 11 items that tapped participants' willingness to interact with education robots in the future (*Contact Intentions*). We asked whether participants would engage in future with education robots should they be given the option. Among others, we used the following items: "I would like to learn together with an education robot", "I am eager to have an education robot at home" or "I would like to prepare for exams together with an education robot". Higher values reflect greater willingness to learn with education robots.

3.3.2 Predictors of Education Robot Acceptance

In order to explore predictors of attitudes toward education robots, we assessed participants' demographic variables (gender, age, education, and occupation). Moreover, we measured respondents' need for cognition (NFC), technology commitment (TC), and prior robot experience (PRE).

NFC reflects the extent to which people strive for effortful cognitive activities [14]. Previous research found a positive relationship between NFC and scientific interest [28]. Importantly, in the context of learning and education with the latest technological developments this variable should significantly predict people's attitudes toward learning with robots. To assess NFC we administered the 10-item German version of the NFC scale proposed by Bless et al. [28]. Example items read: "I would prefer complex to simple problems" or "I prefer my life to be filled with puzzles that I must solve".

We measured participants' commitment in technology using the German version of the *Technology Commitmen*t scale by Neyer, Felber, and Gebhardt [29]. Example items read: "I am very curious about new technical developments", "Dealing with new technical developments is overtaxing me" or "I am eager to use the latest technical gadgets".

Finally, three items captured participants' previous experience with robots in general ("Have you ever seen a real robot?", "Have you ever interacted with a robot", and "Have you ever used, or are you currently using a robot at home or at work?").

3.3.3 Application Potentials for Education Robots

Three items investigated participants' opinion about application potentials for education robots in learning situations. For the item "In what learning situations education robots should primarily be used?" multiple responses were possible (individual learning, group learning or learning in the classroom community). In replying to the item "In what classes should education robots preferably be used?" participants could rate for each subject (e.g., mathematics, arts, education) on the described 7-point Likert scale. For the item "What role should an education robot perform in your opinion?" participants could choose between 'tutor', 'teaching assistant' or 'independent teacher'.

4 Results

4.1 Demographics and Descriptive Statistics

Table 1 presents an overview of the demographical characteristics of the sample. $N = 345$ German respondents (199 females, 146 males), aged between 15 and 60 years ($M = 25.68, SD = 7.48$), participated in the survey. The major part of the respondents had a university entrance diploma or higher. The majority were university students from different disciplines. $N = 176$ studied or worked in technical fields, whereas $n = 139$ studied or were employed in the social sector. Table 2 provides an overview of the mean values, standard deviations, minimal and maximal scores as well as reliability indices values (Cronbach's α) for the measures.

Table 1 Demographics

Characteristic	Total ($n = 345$)
Sex	
Female	199
Male	146
Age ($M = 25.68$, $SD = 7.48$)	
15–30 years	293
30–50 years	41
>50 years	11
Education	
Secondary education	4
Vocational education	11
High school diploma	212
University degree	114
School student	4
Occupation/ Field of study	
Social (e.g., Psychology, Education, Sociology, Medicine)	139
Non-social (e.g., Engineering, Informatics, Economy, Technology)	176
Not reported	30

4.2 Attitudes Toward Education Robots

One-sample t-tests against the neutral midpoint of the scale (scale value = 4 on a 7-point Likert scale) revealed that participants held rather neutral attitudes toward education robots ($M = 4.06, SD = 1.05$), $t(344) = 1.03$, $p = 0.31$. Further, it was found that respondents reported a modest level of education robot anxiety ($M = 3.91, SD = 1.13$), $t(344) = -1.55$, $p = 0.12$. Concerning contact intentions, a significant deviation from the mean value was observed indicating that participants were rather unwilling to interact and learn with an education robot in the future ($M = 3.24, SD = 1.65$), $t(344) = -8.65$, $p < 0.001$. Figure 1 provides an overview of the results.

4.3 Predictors of Education Robot Acceptance

We conducted hierarchical multiple regression analyses to examine whether negative attitudes toward education robots, education robot anxiety, and contact intentions can be predicted by gender (dummy coded: men = 0, women = 1), age, education, occupation (dummy-coded: social careers = 0, non-social careers =1), prior robot experience, NFC, and technology commitment. In the first model of the analysis, we entered the demographic variables gender, age, education, and occupation into the analysis. In the second model, prior robot experience was entered into the analysis. In the third model, NFC and technology commitment were included in the analysis.

4.3.1 Negative Attitudes Toward Education Robots

For the prediction of negative attitudes toward education robots, the third model turned out significant, $R^2 = 0.15$, $F(7, 305) = 6.97$, $p < 0.001$. Technology commitment was the strongest predictor in this model ($\beta = -0.18$, $p = 0.002$), followed by gender ($\beta = 0.17$, $p = 0.008$), NFC ($\beta = -0.13$, $p = 0.02$), and age ($\beta = -0.12$, $p = 0.03$). There was no effect of education or occupation on negative attitudes and likewise, prior robot experience did significantly predict attitudes toward education robots. For a detailed overview of the results, see Table 3.

4.3.2 Education Robot Anxiety

Results regarding education robot anxiety, revealed that the third model was significant, $R^2 = 0.15$, $F(7, 305) = 7.82$, $p < 0.001$. NFC ($\beta = -0.21$, $p < 0.001$) and age ($\beta = -0.21$, $p < 0.001$) were the strongest predictors of education robot anxiety. Further, technology commitment had a significant negative effect on education robot anxiety ($\beta = -0.14$, $p = 0.02$). Gender was only a marginally significant predictor of education robot anxiety ($\beta = 0.11$, $p = 0.06$). Education, occupation, and prior robot experience did

Table 2 Descriptive statistics and internal consistencies of the measures

Measure	*M*	*SD*	Min	Max	α
Negative attitudes toward education robots	4.06	1.03	1.43	6.93	0.83
Education robot anxiety	3.91	1.13	1.00	6.73	0.87
Contact intentions	3.24	1.65	1.00	7.00	0.97
Need for cognition	3.19	1.05	1.00	7.00	0.81
Technology commitment	5.13	0.96	2.33	7.00	0.85
Prior robot experience	2.45	1.58	1.00	7.00	0.85

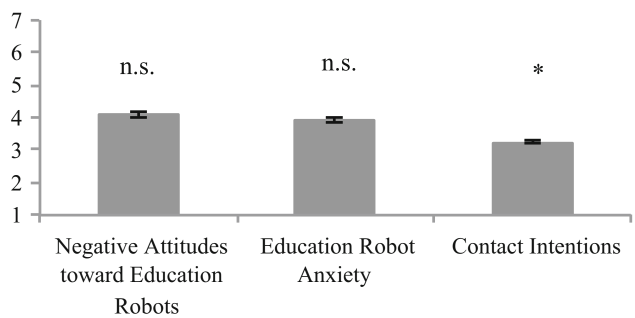

Fig. 1 Mean values and SEs for negative attitudes toward education robots, education robot anxiety, and contact intention

Table 3 Hierarchical regression analyses for negative attitudes toward education robots

	b	SE*b*	β	*CI*
Step 1				
Gender	0.48	0.12	0.24***	0.24, 0.72
Age	−0.02	0.01	−0.11*	−0.03, < 0.001
Education	0.08	0.06	0.08	−0.04, 0.19
Occupation	−0.003	0.12	−0.001	−0.25, 0.24
Step 2				
Gender	0.41	0.12	0.20**	0.16, 0.65
Age	−0.02	0.01	−0.12*	−0.03, −0.001
Education	0.07	0.06	0.07	−0.04, 0.19
Occupation	0.05	0.13	0.03	−0.20, 0.30
PRE	−0.09	0.04	−0.14*	−0.17, −0.02
Step 3				
Gender	0.34	0.13	0.17**	0.09, 0.59
Age	−0.02	0.01	−0.12*	−0.03, −0.002
Education	0.07	0.06	0.07	−0.04, 0.18
Occupation	0.10	0.12	0.05	−0.15, 0.34
PRE	−0.06	0.04	−0.09	−0.13, 0.02
NFC	−0.15	0.06	−0.13*	−0.27, −0.02
TC	−0.19	0.07	−0.18**	−0.32, −0.07

$R^2 = 0.07$ for Step 1; $\Delta R^2 = 0.09$, $p = 0.04$ for Step 2; $\Delta R^2 = 0.15$, $p < 0.001$ for Step 3.
CI 95 % confidence intervals, *PRE* prior robot experience, *NFC* need for cognition, *TC* technology commitment
$*p < 0.05$, $**p < 0.01$, $***p < 0.001$

not predict education robot anxiety. Table 4 summarizes the results of the regression analyses.

4.3.3 Contact Intentions

Results of the hierarchical regression show that the predictors included in the third model had a significant effect, $R^2 = 0.12$, $F(7, 305) = 6.15$, $p < 0.001$. Technology commitment was the strongest predictor of contact intentions toward education robots ($\beta = 0.23$, $p < 0.001$), followed by education ($\beta = -0.16$, $p = 0.004$), and gender ($\beta = -0.13$, $p = 0.04$). Interestingly, age, prior robot experience, NFC, and occupation had no significant impact. Table 5 displays a detailed overview of the results for the three models.

4.4 Application Potentials for Education Robots

We calculated percentage frequencies for preferred learning scenarios for education robots, preferred role of education robots, and application preferences for various subjects (multiple references were possible).

When asked to provide examples for potential learning contexts in which education robots could be placed, approximately 77 % of the respondents reported that they would prefer education robots in individual learning contexts. That is, respondents preferred to learn in a team with an education robot instead of learning with the education robot and another person. About 24 % stated that they would use education robots in group-learning situations. Only 14 % of the participants would use education robots for learning in the whole classroom community. Figure 2 presents the percentage distribution of the preferred learning scenarios for education robots.

As shown in Figure 3, 68 % of the respondents favored robots as teaching assistants regarding the role of education robots in learning situations. Almost a half of the participants (47 %) preferred education robots in the role of a tutor. Merely 8 % would use an education robot as an independent teacher.

With respect to preferred fields of application, one-sample *t*-tests against the neutral midpoint of the scale (scale value = 4 on a 7-point Likert scale) revealed that

Table 4 Hierarchical regression analyses for education robot anxiety

	b	*SEb*	*β*	*CI*
Step 1				
Gender	0.36	0.14	−0.16**	0.09, 0.63
Age	−0.03	0.01	−0.20**	−0.05, −0.01
Education	−0.04	0.07	−0.03	−0.17, 0.09
Occupation	−0.06	0.14	−0.03	−0.33, 0.22
Step 2				
Gender	0.30	0.14	0.13*	0.01, 0.57
Age	−0.03	0.01	−0.20***	−0.05, −0.01
Education	−0.04	0.07	−0.03	−0.17, 0.09
Occupation	−0.01	0.14	−0.003	−0.29, 0.27
PRE	−0.09	0.04	−0.11*	−0.17, −0.01
Step 3				
Gender	0.25	0.14	0.11†	−0.03, 0.52
Age	−0.03	0.01	−0.21***	−0.05, −0.02
Education	−0.04	0.06	−0.03	−0.16, 0.09
Occupation	0.03	0.14	0.01	−0.24, 0.30
PRE	−0.05	0.04	−0.07	−0.13, 0.04
NFC	−0.26	0.07	−0.21***	−0.40, −0.12
TC	−0.17	0.07	−0.14*	−0.31, −0.03

$R^2 = 0.07$ for Step 1; $\Delta R^2 = 0.09$, $p = 0.06$ for Step 2; $\Delta R^2 = 0.15$, $p < 0.001$ for Step 3.
CI 95 % confidence intervals, *PRE* prior robot experience, *NFC* need for cognition, *TC* technology commitment
† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5 Hierarchical regression analyses for contact intentions

	b	SE*b*	*β*	*CI*
Step 1				
Gender	−0.63	0.20	−0.19**	−1.03, 0.24
Age	0.02	0.01	0.08	−0.01, 0.04
Education	−0.29	0.10	−0.17**	−0.47, −0.10
Occupation	−0.10	0.20	−0.03	−0.51, 0.30
Step 2				
Gender	−0.60	0.21	−0.18**	−1.01, 0.20
Age	0.02	0.01	0.08	−0.01, 0.04
Education	−0.28	0.10	−0.17**	−0.47, −0.09
Occupation	−0.13	0.21	−0.04	−0.53, 0.28
PRE	0.04	0.06	0.04	−0.08, 0.16
Step 3				
Gender	−0.43	0.21	−0.13*	−0.84, 0.03
Age	0.02	0.01	0.08	−0.01, 0.04
Education	−0.27	0.09	−0.16**	−0.45, −0.09
Occupation	−0.24	0.20	−0.07	−0.64, 0.17
PRE	−0.01	0.06	−0.01	−0.14, 0.11
NFC	0.13	0.10	0.07	−0.07, 0.34
TC	0.40	0.11	0.23***	0.19, 0.61

$R^2 = 0.07$ for Step 1; $\Delta R^2 = 0.07$, $p = 0.40$ for Step 2; $\Delta R^2 = 0.12$, $p < 0.001$ for Step 3.
CI 95 % confidence intervals, *PRE* prior robot experience, *NFC* need for cognition, *TC* technology commitment
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

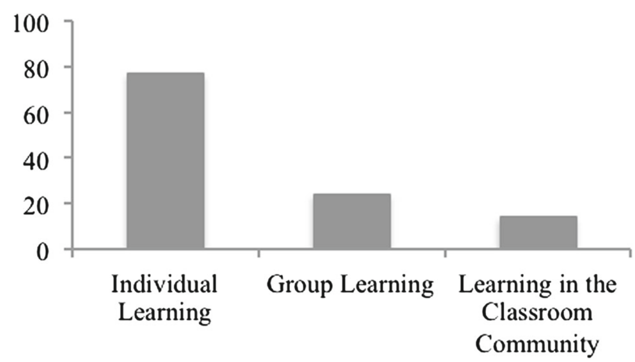

Fig. 2 Percentage distribution of preferred learning scenarios for education robots

respondents would apply education robots predominantly in STEM-related fields, e.g., informatics ($M = 5.35, SD = 1.88$), $t(339) = 14.00$, $p < 0.001$, mathematics ($M = 5.08, SD = 1.91$), $t(341) = 10.97$, $p < 0.001$, physics ($M = 4.73, SD = 1.82$), $t(342) = 7.93$, $p < 0.001$, and biology ($M = 4.24, SD = 1.73$), $t(338) = 2.57$, $p = 0.01$.

Interestingly, participants were willing to use education robots to teach foreign languages ($M = 4.39, SD = 2.03$), $t(339) = 3.68$, $p < .001$, but not for teaching German language ($M = 2.91, SD = 1.81$), $t(337) = -11.02$, $p < .001$.

Respondents were not inclined to use education robots in social sciences and fine arts: In domains like music ($M = 2.95, SD = 1.95$), $t(341) = -10.06$, $p < 0.001$, politics ($M = 2.90, SD = 1.81$), $t(338) = -11.13$, $p < 0.001$, education ($M = 2.19, SD = 1.61$), $t(337) = -20.06$, $p < 0.001$, and arts ($M = 1.97, SD = 1.49$), $t(335) = -25.50$, $p < 0.001$, respondents were not eager to learn with an education robot. For history ($M = 4.01, SD = 2.05$), $t(337) = 0.24$, $p = 0.81$, respondents were neutral toward using education robots in this subject. Figure 4 depicts an overview of the application preferences for education robots in various subjects.

5 Discussion

To investigate attitudes toward education robots in the European context more extensively, we have explored negative attitudes toward education robots, education robot anxiety, and contact intentions to education robots among a German sample. Importantly, we have examined the role of key predictors on respondents' attitudes and have investigated application potentials of education robots regarding learning situations, robotic role, and preferred subjects.

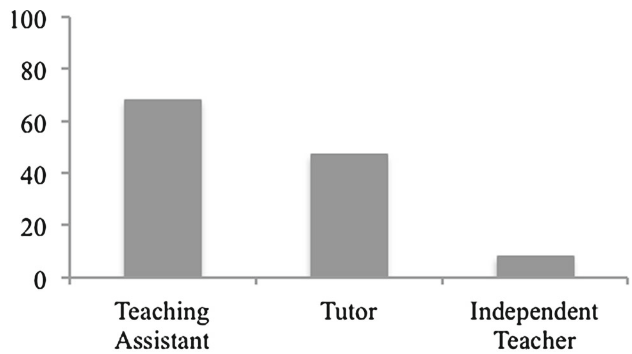

Fig. 3 Percentage distribution of preferred role for education robots in learning scenarios

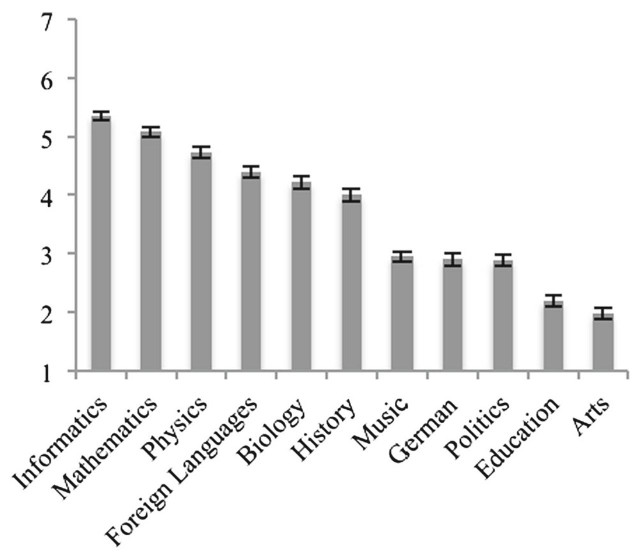

Fig. 4 Mean values and SEs for the application preference in various subjects

We did so, in order to fill the existing gaps in literature: We captured attitudes toward education robots in another European country, namely Germany. To address the lack of investigation of predictors on attitudes toward education robots, we explored the role of demographic variables (gender, age, education, and occupation), prior robot experience, NFC, and technology commitment. Finally, we assessed participants' view regarding the preferred applicability of educational robots in the learning context, an underresearched aspect so far.

5.1 Attitudes toward Education Robots

Our results suggest that Germans had neutral attitudes toward education robots and were also opposed neutral toward the idea of learning with an education robot.

However, respondents reported modest education robot anxiety, low contact intentions and were hesitant to learn with an education robot in future.

Apparently, the application domain were robots should be deployed clearly affects people's attitude. For instance, findings by the Eurobarometer survey [2] showed that EU citizens held a positive attitude toward robots in general, in particular toward robots used in industry, healthcare, and domestic areas. Reich and Eyssel [3] also found that German people were rather positive toward service robots for domestic environments. Obviously, German people nowadays have more positive attitudes toward robots that could bring benefits to their lives. Nevertheless, both surveys also have shown that people were quite reluctant when it comes to the use of assistive robots in everyday life. Respondents in the Eurobarometer study [2], for example, rejected robots in educational contexts. Reich and Eyssel [3] have furthermore found that German people—although they held rather positive attitudes toward service robots—were not eager to use them in their home. This observed reservation toward companion robots in everyday life might be explained by the fact that robots are not yet common in the German context, especially not in educational settings. An implication of this finding may therefore be the need to introduce education robots slowly into the school and other learning environments before making education robots available for every learner in the next step. Promotional campaigns and visits in schools would be an opportunity to slowly attract students and teachers into learning and working with educational companion robots.

5.2 Predictors of Education Robot Acceptance

5.2.1 Role of Gender

In H1, we predicted that female participants would report a greater amount of negative attitudes toward education robots and education robot anxiety compared to male respondents. Moreover, female respondents should report lower contact intentions. Results support this effect for negative attitudes toward education robots and for contact intentions. Women report higher negative attitudes and less willingness to interact and to learn with education robots in future than men. Findings for education robot anxiety narrowly failed statistical significance, nevertheless showing the same trend with male respondents reporting less anxiety toward education robots. These results are similar to those found in various studies [2,3,7,30,31] with women having a more negative attitude toward robots indicating that robotics at the present seems to be a male domain. Another study that evaluated the relationship between the social presence of a robot and gender observed that female participants saw a robot as more machine-like while males tended to see the robot as more human-like [32]. This supports further the 'gender and technology assumption', this is, that men have a stronger affinity with technology than women who tend to dislike it [33]. With respect to this, female participants dislike education robots more than male participants do, as robots represent one of the latest technological devices. However, it should not be extrapolated from our findings that education robots should be applied for males only or in lessons that are mainly taken by boys (e.g., STEM-related fields). On the contrary, learning with education robots could be even suitable in order to familiarize women with new technologies. Particularly when bearing in mind that education robots have the capacity to interact in a more social way with humans, which may lead to a more positive and open attitude toward education robots and probably resulting in less reluctance toward technological issues in general. These assumptions are corroborated by findings by Kennedy, Baxter, and Belpaeme [34], who found that female participants outperformed males when learning with a social robot. Additionally, females who learned with a robot present improved more than those who learned without a robot present. To develop a broader picture of the link between gender and attitudes toward education robots and learning with education robots respectively, additional studies will be needed on this association.

5.2.2 Role of Age

In H2, we hypothesized that negative attitudes toward education robots and education robot anxiety should increase with age, whereas contact intentions should reduce, correspondingly. Findings show that the opposite is the case: Younger participants report significantly more negative attitudes toward education robots and education robot anxiety. Concerning contact intentions, no impact of age was observed indicating that across age respondents are quite unwilling to interact and to learn with education robots. A possible explanation for the unexpected findings could be that older respondents were more positive toward education robots because the prospect of real learning with robots is less likely for them as it is for younger participants. This assumption is supported by the fact that when asked for contact intentions, all participants were rather unwilling to learn with education robots. Nevertheless, this finding must be interpreted with caution because the age distribution in our sample does not include all age groups. A major part of our respondents was at the age of around 25 years. Future studies, which include attitudes of younger school students, will need to be undertaken.

5.2.3 Role of Education

In H3, we had predicted that participants would report less negative attitudes, less education robot anxiety, and more contact intentions as a function of educational level. Unexpectedly, however, education level had no influence on negative attitudes and education robot anxiety. This finding thus does not correspond with findings of the Eurobarometer study [2] that demonstrated that education level was positively related to positive attitudes toward robots in general. With respect to contact intentions, results were in contrast to our predictions: The higher participants' education level, the less they were willing to learn with an education robot. It may be that participants with higher education level doubt that education robots could provide helpful assistance concerning the more complex contents that are treated in higher education.

5.2.4 Role of Occupation

In H4, we had proposed that respondents that study or work in the social sector would report more negative attitudes and more education robots anxiety, and analogously less contact intentions compared to participants working in social domains. However, field of study or occupation did neither influence negative attitudes, education robot anxiety, nor contact intentions. These results imply that technology commitment probably affects career choice so that an effect of field of study and occupation fails to appear.

5.2.5 Role of Prior Robot Experience

Due to the ambiguous findings regarding previous robot experience [2,3], we investigated the effect of prior robot experience on negative attitudes toward education robots, education robot anxiety, and contact intentions. In line with Reich and Eyssel [3], we found that prior robot experience does not occur as significant predictor of negative attitudes, education robot anxiety, and contact intentions toward education robots when it is examined simultaneously with technology commitment (H5). In this way, our results support findings by Reich and Eyssel [3] and contradict previous results that highlight the effect of prior robot experience on attitudes toward robots (e.g., [2,5,31]). A possible explanation might be that respondents gained experiences with robots because of their interest in technological issues so that it is not prior robot experience that affects attitudes toward education robots but technology commitment itself. A further explanation might be due to prior robot experience itself as results showed that the major part of the participants had gathered no or only few experiences with robots. As mentioned above, robots are not common in Germany. Thus, it seems to be difficult to investigate the impact of this factor at the moment.

5.2.6 Role of Need for Cognition

In H6, we hypothesized that participants high in NFC would hold less negative attitudes and less education robot anxiety than participants low in NFC. Further, they would report more contact intentions to education robots. Results confirm our hypothesis for the most part: Respondents high in NFC stated less negative attitudes toward education robots as well as less education robot anxiety. These findings may be due to the fact that people high in NFC are more interested in scientific discoveries [28] and thus, are less negative and skeptical toward education robots. Regarding contact intentions, no effect was found. Although respondents high in NFC held a more positive view toward education robots, they seemingly were just as disinterested as participants low in NFC in learning with an education robot in the future. This finding further underlines participants' reservations to learn with education robots in future, regardless of their attitudes toward them.

5.2.7 Role of Technology Commitment

In H7, we had predicted that participants with high technology commitment would report less negative attitudes, less education robot anxiety, and more contact intentions, respectively. This prediction was fully supported: Negative attitudes and education robot anxiety decreased as a function of respondents' technology commitment. Analogously, willingness for future learning with an education robot rose with increasing technology commitment. Our findings yield further evidence for the significant influence of interest in technological issues on attitudes toward robots, as robots present a form of the latest technological achievements.

5.3 Application Potentials for Education Robots

Regarding application potentials for education robots in learning situations, the majority of respondents considered that robots should preferably be applied in individual learning scenarios. Thus, people primarily prefer to learn with an education robot individually and not with other persons. Learning with education robots in group-learning situations was named on second place. Only a small proportion of respondents could imagine using education robots in in the classroom community.

A possible explanation for these results may be the practiced teaching and learning habits in schools and universities. Nowadays, most of the classroom and learning activities have developed from teacher-centered lectures and lessons to self-regulated individual and group learning situations. This might be strongly related to people's preference for learning with a robot one to one or in smaller groups in order to adapt the use of education robots to the latest requirements in education, namely, autonomous and self-directed learning that is independent of the learning speed and process of the whole class community.

Another possible explanation for the findings might be the participants' cultural background. There are two main contrasting cultural orientations that have a strong influence on people's self-conception and identity. These are, individualism and collectivism. Individualistic cultures emphasize the individual and personal achievement; the self is seen as independent [35]. Collectivistic cultures, however, emphasize family and group goals above individual needs; the self is seen as interdependent [35]. Individualistic cultures are prevalent in American and West European countries whereas collectivistic cultures are assumed to be more traditional societies like the East Asian cultures [36,37]. Our results may be explained by the fact that Germany is considered to be an individualistic culture. Thus, participants in our sample probably prefer individual learning with an education robot because they are shaped by a society that emphasizes the individual and its personal progress.

The above-described results are in accordance with the findings regarding the robotic role: Most of the respondents indicated that they would favor education robots in the role as a tutor or teaching assistant. Just a small part of participants could imagine that education robots could act as independent teachers in the classroom. Obviously, participants were convinced that education robots are not able to act autonomously in classroom learning scenarios. These findings suggest that education robots are deemed as support for the learning of singular persons or small groups, but not as independent teachers that are responsible for the learning progress of a whole class. Relating these outcomes to the prospective use of education robots in school and higher education, it might be feasible to use multiple education robots in the classroom instead of using one single robot, for instance. In this case, various learning groups could use an education robot to support their learning. This would ensure that students could learn in more individual interaction situations with the robot and it could prevent waiting periods and disagreements between students, as it would be the case when only a single education robot was available.

With respect to preferred fields of application, results clearly show that education robots are perceived particularly useful in STEM-related areas like computer science, mathematics or physics. This is not surprising because technical systems like the Lego Mindstorms [38] are already applied in these fields. Participants also reported that they would utilize education robots to teach foreign languages and history. This might be due to the fact that these subjects require testing a lot of objective and factual knowledge (e.g., vocabulary, data), which can easily be examined by a robot. Another possible explanation might be that these domains do not require abstract thinking or creativity, as it would be needed in social and cultural disciplines. In fact, the application in social and cultural subjects (e.g., politics, education, arts) was rather rejected by the majority of respondents. An issue that emerges from this is the possibility to introduce education robots into German learning contexts primarily in STEM-related subjects. This would meet the expectations of

German learners, and as a next step the application of education robots could be extended to other less technical and scientific learning fields.

6 Methodological Remarks and Outlook

Although the results in our survey are promising and have demonstrated that it is crucial to consider various factors when introducing robots into social contexts like university, school and other learning settings, some methodological aspects and future directions for further research need to be discussed.

A critical aspect of our methodology lies in the fact that we only used a written description of the features and functions of education robots without providing picture material of different types of already applied education robots. From a methodological point of view, this was necessary to avoid confounding results due to the exterior appearance the robots on the pictures would have. To illustrate, using the picture of the robot NAO [22] might have lead participants to adopt a more critical stance toward NAO's abilities to express emotional reactions in conversations (e.g., when replying to the item "I would feel comfortable when learning with an education robot that has emotions") due to the fact that the robot NAO has no facial parts that can be moved in order to express emotions. Nevertheless, it should be considered to use pictures of educational robots in future studies in order to ensure that people have a better imagination of education robots' appearances and capabilities. Additionally, future research could usefully investigate people's attitudes on the appearance that robots for learning purposes should have. In this regard, findings on different robot embodiments and appearances in learning contexts already indicate that humanoid and animal-shaped robotic designs were more popular among 3rd to 5th grade children than object-based designs like desktop objects or geometric shapes [39]. Thus, more research needs to be undertaken to deepen our understanding of effective robot design elements for smooth and successful learning interactions.

Regarding the generalizability of our results, the sample was representative of university students but would tend to miss participants from other learning institutions. Thus, the age and education range of our sample was to some extent homogeneous. Future research should therefore concentrate on the investigation of school students', teachers' and parents' attitudes toward learning and working with education robots in school. Moreover, future work needs to investigate in more detail people's expectations and reservations toward learning with robots. In order to do so, it is suggested that upcoming studies should also use open questions to leave more room for participants' assumptions, worries, or ideas on how to learn with education robots. To address these issues, research is underway to expand our knowledge on attitudes toward education robots among different primary users in German schools (e.g., school students, teachers, parents).

More information on these points would help to establish a better understanding of how to design education robots and which functions and features should be included. Finally, as we conducted our survey online, in future research other formats of investigation (pen and paper questionnaires or verbal interviews) are needed in order to reach target groups that are not familiar with or have no access to computers like younger school and pre-school children.

7 Conclusion

The present research contributes to the existing literature by capturing attitudes toward education robots among another European country and by investigating German university students' attitudes toward another specific robot type. Moreover, our results go beyond previous research on attitudes toward education robots in two ways: First, we investigated predictors of attitudes toward education robots. Second, we put emphasis on the participants' view regarding the preferred applicability of education robots in the learning context.

In sum, results demonstrate that German university students have rather neutral attitudes toward education robots and our respondents appeared rather reluctant to learn with them. These findings contribute additional evidence that German people currently do not have a concept of education robots because social robots are not widespread in the German context. However, it is important to bear in mind that some of the participants have completed their educational career, thus being less concerned about this topic. Therefore, future research should consider data from a wider range of participants who are actually and currently facing the situation that robots could be co-teaching and assisting in the classroom during their period of formal (higher) education, e.g., primary school children, teachers, and parents. Moreover, future research should apply a more detailed description of the features and functions of education robots, maybe also including images of already existing education robots. In addition, it would be interesting to investigate perceptions of different robot types that could be applied in learning contexts.

Another finding was that demographic variables (gender, age, and education), NFC, and technology commitment were significant predictors of attitudes toward education robots and of contact intentions. These points are of major importance in light of the fact that robots will enter the education sector increasingly in the near future. Findings from our research could help to implement educational robots in line with the expectations of potential end-users. To illustrate, an implication of this is the option to introduce education robots into the school context primarily in STEM-related subjects before expanding the use to more social and cultural subjects. Additionally, results of this study suggest that education robots should be utilized as teaching assistants. Education robots in the German context should therefore be used to support the teaching process instead of acting independently.

From a more general perspective, it is important to provide further empirical evidence on how aspects like culture, robot type, and individual characteristics influence attitudes toward robots. Further research that takes these aspects into consideration is therefore underway. Finally, as our survey revealed people's perceptions and reservations toward education robots and predictors that affect these, our findings provide new insights into how to integrate education robots in order to meet the expectations people have toward companion robots in school und university contexts.

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Natalia Reich-Stiebert is a Ph.D. student in the research group "Gender and Emotion in Cognitive Interaction" at the Center of Excellence in Cognitive Interaction Technology (CITEC) in Bielefeld. She received her Bachelor and Masters degree in Psychology and Romanic Philology (M.Ed.) from the Technical University of Dortmund and the Ruhr University of Bochum. In her research, she investigates attitudes toward robots and impact factors on robot acceptance. Furthermore, she is interested in examining factors that are necessary for successful cooperative learning with educational robots.

Friederike Eyssel is currently a Visiting Associate Professor at New York University Abu Dhabi. Moreover, she is head of the research group "Gender and Emotion in Cognitive Interaction" at the Center of Excellence in Cognitive Interaction Technology (CITEC) at Bielefeld University. Friederike Eyssel earned her Masters Degree in psychology from University of Heidelberg (Germany) in 2004. She received her Ph.D. in psychology from University of Bielefeld (Germany) in 2007. Dr. Eyssel has held visiting professorships in social psychology at the University of Münster, the Technical University of Dortmund, and the University of Cologne. Dr. Eyssel is passionate about basic and applied social psychological research and she is interested in various research topics ranging from social robotics, social agents, and ambient intelligence to attitude change, sexual violence, dehumanization, and prejudice reduction. Crossing disciplines, Dr. Eyssel has published her research not only in the field of social psychology, but also in in human–robot interaction and social robotics. Current third-party funded research projects address user experience, smart home technologies and social and ethical aspects of assistive technology.