Keep an Eye on the Task! How Gender Typicality of Tasks Influence Human–Robot Interactions*

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Abstract. In the present experiment, we tested the impact of the gender typicality of a human–robot interaction (HRI) task on the user's performance during HRI, and on evaluation and acceptance of the robot. $N = 73$ participants (38 males and 35 females) performed either a stereotypically male or a stereotypically female task while being instructed by either a 'male' or a 'female' robot. Our results revealed that gender typicality of the task substantially influenced our dependent measures: Specifically, more errors occurred when participants collaborated with the robot in context of a typically female work domain. Moreover, participants were less willing to accept help from the robot in a future task when they performed a typically female task. These effects were independent of robot and participant gender. Furthermore, when instructing participants on a female task, the male and the female robot were perceived as equally competent. In contrast, when instructing participants on a male task, the female robot was perceived as more competent compared to the male robot. Our findings will be discussed with regard to theoretical and practical implications.

Keywords: Gender, human-robot interaction, robot evaluation.

1 Introduction

Imagine that we would offer you a robot that could provide assistance for any given task you deemed suitable. How should such a robot ideally look like? Which name should it have? Would you prefer a male or a female robot? Importantly, what kind of work should the robot get done? Most people might now think about a robot that would clean the house or do the dishes, a robot that would provide help on tasks we often find annoying, time-consuming, or that are hard to handle on our own. Indeed, many already existing and newly developed robots are supposed to assist people with tasks such as doing daily household chores (MOVAID, [1]), providing medical services (e.g., measuring blood pressure, Hopis, [2]), collecting and delivering commodities or food (MOVAID, [1]), and serving as a social companion and communication

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partner (iCat; [3]). Interestingly, a closer look at these domains of application for robots reveals that they are closely associated with societal gender roles. That is, these tasks can be categorized in terms of 'typically female' versus 'typically male' tasks [e.g., 4, 5]. More specifically, many robot applications seem to be associated with traditionally female work domains (e.g., housework, health care). In the present research, we will address this gender typicality of a human–robot interaction (HRI) task and investigate whether this gender factor influences how users perceive and interact with a robot.

Gender is one of the most salient and omnipresent social categories in human societies that affects virtually every aspect in our every-day live. To a large extent, gender determines people's social roles, occupations, relationships, and opportunities [6]. Importantly, gender can be seen as the primary and most basic category of social perceptions of others and of the self [7]. Consequently, our own gender and the gender of others influence how we think about and interact with each other. Similar to human–human social interactions, gender also could largely impact humans' perceptions of and interactions with *robots*. Research so far has investigated gender effects in HRI mostly from two different angles: The alleged robot gender (as indicated, e.g., by its appearance, behavior, or name) and the user's gender.

In the eyes of users, robots often do not appear gender-neutral, but instead are perceived as male or female prototypes. To illustrate, Eyssel and Hegel [8] have demonstrated that a visual cue, such as a robot's hair length leads to differential ascriptions of masculinity or femininity to a social robot. Similarly, vocal cues also serve to indicate a robot's gender [9]. Importantly, the alleged gender of a robot affects the user's reactions toward the robot. For instance, in the study by Eyssel and Hegel [8], participants ascribed the 'male' robot more stereotypically male traits (e.g., competence) and perceived it as more suitable for stereotypically male tasks than the apparently female robot. In contrast, the 'female' robot was ascribed more stereotypically female traits (e.g., warmth) and was perceived more suitable for typically female tasks. Moreover, Powers and colleagues [10] demonstrated that people use knowledge about gender roles when interacting with a gendered robot. In this study, participants elaborated less on a typically female topic (i.e. dating norms) when talking to an ostensibly female robot than when talking to a 'male' robot.

Despite robot gender, user gender also has an impact on the users' reactions toward robots. However, findings are not consistent. Research by Siegel, Brezeal, and Norton [11], for instance, indicates that users evaluate a robot of the opposite gender more positively than a same-gender robot; they even tend to behave more positively toward robots of the opposite gender. In contrast, Eyssel and colleagues [9] found that participants perceived a *same*-gender robot significantly more positive and psychologically close than the opposite-gender robot. Moreover, the same-gender robot was anthropomorphized (i.e., ascribed uniquely human attributes) to a greater extent compared to the opposite-gender robot. Unlike these results, Schermerhorn, Scheutz, and Crowell [12] found a general tendency for male users to perceive a robot as more human-like compared to female users.

In sum, the results reviewed here demonstrate that robot and user gender seems to elicit complex effects in HRI. However, also the different types of tasks a robot performs might be perceived as being either stereotypically 'male' or stereotypically 'female' [see 8]. Thus, despite robot and user gender, the perception of gender typicality of a task could impact how people will interact with a robot on the specific task. First evidence that features of a task together with user and robot features differentially influence HRI and perceptions of a robot comes from Mutlu and colleagues [13]. In their experiment, males and females played an interactive video game with a robot, and they did so either in a cooperative or in a competitive way. The results showed that men based their evaluation of the robot to a large extent on the different features of the tasks, whereas women were more influenced by the characteristics of the robot. In a different set of studies [14], participants found a robot more suitable for a task when the degree of the robot's humanlikeness matched the degree of sociability required by the task. Thus, task characteristics indeed could influence humans' perceptions of a robot and HRI quality. However, previous studies have not yet considered the gender typicality of different tasks as an important aspect that could influence HRI, although many domains of robot applications are closely associated with societal gender roles.

In the present exploratory experiment, we therefore investigated for the first time the impact of gender typicality of an HRI task on humans' task performance during HRI and on humans' evaluation and acceptance of the robot. Moreover, we also tested the interplay of this gender factor with user and robot gender.

2 Method

2.1 Participants

$N = 73$ German participants (38 males, 35 females) with a mean age of 25.00 years ($SD = 4.29$) took part in our study. They were randomly assigned to one of four experimental conditions that resulted from a 2 (*gender typicality of task*: Male vs. female) x 2 (*robot gender:* Male vs. female) between–subjects factorial design: Accordingly, together with a robot participants had to solve a task that constituted either a typically male or a typically female task. Moreover, participants interacted either with an allegedly male or female robot.

2.2 Procedure

Participants were tested individually in the laboratory at Augsburg University. They were sitting in front of a Microsoft Surface[1] touch-screen table opposite to the robot NAO (Academic Edition V3.2, Aldebaran Robotics). On the touch-screen, different items (either sewing accessories or tools, see Fig. 1) and a container (either a sewing box or a toolbox, see Fig. 1) were depicted[2]. Initially, the experimenter briefly

[1] `http://www.microsoft.com/surface/`

[2] We used the Microsoft Surface instead of a real tool or sewing box because this enabled a stable tracking of the location of the items and logging the participants' input without using the robot's vision system. The robot calculated the positions of the items with the data from the Microsoft Surface. This way, we were able to control details of the HRI set-up, such as the size of the items and compartments as well as the initial item positions.

introduced the participants to the robot and mentioned the robot's alleged name (either the male name NERO or the female name NERA). Participants were then informed that they would work on a sorting task together with the robot and that the robot would instruct them on the task. The robot operated fully autonomously during the experiment. After a short tutorial with two sample trials, participants completed 15 critical trials of the sorting-task. On average, the interaction between participant and robot lasted for approximately 10 minutes. Subsequently, the experimenter asked participants to complete several computerized questionnaires that contained our dependent measures. Finally, participants were reimbursed, debriefed and dismissed.

2.3 Human–Robot Interaction Task

Experimental set-up. On the touch-screen table, participants were presented with a container that consisted of 10 compartments that were of small, medium, and large size. Moreover, participants saw nine items that were already sorted into the different compartments of the container. Fifteen further items were distributed around the container. These unsorted items had to be sorted into different compartments of the container. All but three items could be grouped into nine object categories (e.g. different types of scissors or water levels). Each category was represented by at least two items. Importantly, one item of each category was already stored in the container (see Fig. 1). This was done in order to give participants guidance where the remaining objects could be stored. In addition, three remaining unsorted items did not belong to any of the nine categories. Figures 1a and 1b depict the set-up of the sorting task.

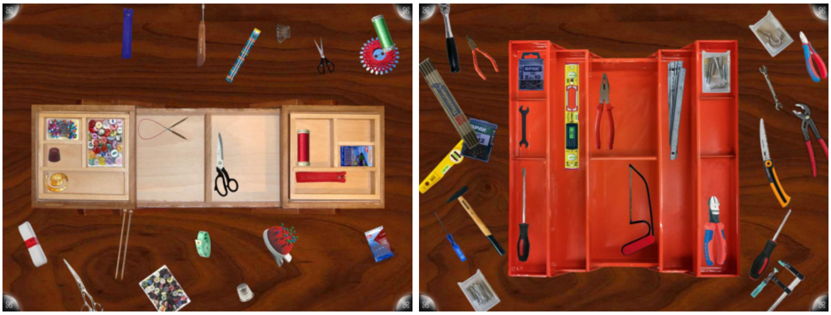

Fig. 1. Pictures of the experimental set-up: On the left side a sewing box with sewing accessories, on the right side a tool box with tools

Instructions. In each of the 15 trials, participants received two instructions from the robot: The first instruction was the *selection instruction* that concerned the choice of the object (e.g., 'Pick the small scissors.'). This instruction included a specific description of the respective item (e.g., name, size, color if applicable). Moreover, following the procedure by Ishiguro and colleagues [15], each selection instruction was accompanied by a pointing gesture and a gaze toward the object. The participant was then supposed to select the respective item by tapping on it with his or her fingers. The robot verbally confirmed a correct choice (e.g., 'This is correct.'). In case of a wrong choice, the robot rejected the choice of the participants and repeated the instruction.

The second instruction in each trial was the *position instruction*. This instruction specified the target position for the respective item (e.g., ‘Put it in the upper right small compartment.’). Similar to the selection instructions, the position instructions were accompanied by gaze and pointing behavior. However, to make the interaction more realistic and natural [16], participants not always received correct or optimal instructions by the robot. That is, the robot used three different types of *position instructions*: In six of the 15 trials, the robot gave *optimal position instructions* asking participants to put an item into a compartment that already contained an object of the same category. In six further trials, participants received *suboptimal position instructions*. That is, they were instructed to sort an item into a compartment that did not already contain an item of the same category, although an exemplar of the same object category was depicted in one of the other container’s compartments. In three trials, the robot gave *wrong position instructions* and asked participants to put an item into a compartment that was too small to accommodate the chosen item. Thus, participants were obliged to choose an alternative compartment to store the specific item.

When participants followed the robot’s optimal and suboptimal position instructions, the robot commented their behavior with a short feedback (e.g., ‘This is the correct compartment.’). In case participants did not follow the robot’s optimal or suboptimal instructions but chose a *correct* alternative, the robot confirmed that participants made a correct choice by saying ‘This is also possible’. When participants chose an *incorrect* target position for the item (i.e., a compartment that was too small for the item), the robot stated ‘This item does not fit in here’ and repeated the original position instruction. Consequently, the participant had to try again to store the specific item. When participants tried to follow the robot’s wrong instructions and thus chose an incorrect target position, they received the same feedback (‘This item does not fit in here.’). However, the robot also repeated its original (wrong) position instruction. As it was not possible for participants to follow the robot’s wrong instructions, choosing an alternative was necessary.

The trials were realized in a fixed randomized order. The sequence of optimal, suboptimal, and wrong instructions was identical for all experimental conditions.

2.4 Experimental Manipulation

Gender typicality of the task. Participants were confronted with two different types of tasks that have been chosen based on pretests. Participants were either asked to sort different tools into a toolbox. This represented the typically male task. In the female task condition, in contrast, participants were asked to sort sewing equipment into a sewing box. Importantly, besides the expected differences in gender typicality of the tasks, pretests yielded that both tasks were perceived as equally complex and equally demanding.

Gender of the robot. In order to manipulate the alleged gender of the robot, we varied two aspects of the robot: Its name and its voice. Based on pretests, the name NERO was chosen to indicate male gender, and the name NERA was used to indicate female gender of the robot. During the experimenter’s instructions at the beginning of the study, the name of the robot has been mentioned repeatedly. Moreover, the ‘male’ robot spoke with a typically male voice (low frequency), whereas the ‘female’ robot has been equipped with a more female-type voice (high frequency). The voices have been generated by the robot's Text-To-Speech system (Acapela Mobility 7.0) and were selected based on pretests.

2.5 Dependent Measures

Manipulation check. As a manipulation check, we asked participants to indicate on a 7-point Likert scale whether they perceived the robot as being more female or more male. The endpoints of the scale were 1 = 'more female' vs. 7 = 'more male'. Additionally, to ensure that the two types of tasks were not differentially demanding for the participants depending on gender typicality of the task, participants had to indicate on a 7-point Likert scale how difficult they perceived the task.

Performance during HRI. We used three different behavioral indicators for participants' performance during HRI. First, we measured the duration of each of the 15 trials, resulting in an *average duration per trial* (in seconds). Second, we assessed the number of participants' errors for each of the 15 trials. Picking the wrong object or choosing a compartment that did not fit the size of the object was considered an error. Accordingly, we calculated the *average error rate per trial.* These two indicators represent the measures of objective task performance. That is, the longer the average duration per trial, and the higher the average number of errors per trial, the lower the quality of task performance. Third, we measured the number of alternative compartment solutions participants have chosen, that is, the number of times participants did not follow the robot's position instructions. However, after receiving wrong position instructions from the robot, participants were obliged to choose an alternative compartment. Thus, we only considered the number of alternatives after optimal and suboptimal position instructions. Accordingly, we calculated the *average number of chosen compartment alternatives per trail* after optimal and suboptimal instructions. This measure is used as an indicator of participants trust in the robot's instruction.

Robot evaluation. With two items, participants rated the robot's task-related competence ('The robot knew exactly what I had to do in this task.', 'The robot was well informed about the task.'). The endpoints of the 7-point Likert scales were 1 = 'not at all' and 7 = 'very much'. These two items formed a reliable index of task competence of the robot, $\alpha = .82$.

Robot acceptance. To measure robot acceptance, we asked participants to indicate on a 7-point Likert scale how willing they would be to accept help from the robot on a possible future task. The endpoints of the scale ranged from 1 = 'not at all' to 7 = 'very much'.

3 Results

3.1 Manipulation Check

As a manipulation check, we first tested whether participants recognized the alleged gender of the robot. Results of a *t*-test revealed that in the female robot condition the robot was perceived as more female (M = 3.00, SD = 1.63), whereas in the male robot condition the robot was correctly identified as male[3] (M = 6.06, SD = 1.06), $t(70) = 9.38$, $p < .001$, $d = 2.23$.

Moreover, to make sure that participants perceived both sorting tasks as equally demanding, we conducted a *t*-test comparing the typically female and the typically male task. Results indicate no difference between the typically female task (M = 1.31, SD = 0.53) and the typically male task (M = 1.47, SD = 0.61), $t(70) = 1.24$, $p = .22$, $d = 0.28$.

3.2 Performance During HRI

Duration of task completion. Results of a 2 (*gender typicality of task*: Male vs. female) x 2 (*robot gender:* Male vs. female) x 2 (*participant gender*: Male vs. female) analysis of variance (ANOVA) yielded no significant main effects on the duration of task completion, all *p*s > .35. However, we obtained a marginally significant *robot gender* by *participant gender* interaction effect, $F(1, 65) = 2.84$, $p = .10$, $\eta^2 = .04$. Planned *t*-tests revealed that female participants completed the task equally fast, regardless of whether they interacted with an ostensibly female or male robot (M = 5.70 sec., SD = 1.03 vs. M = 5.90 sec., SD = 1.55, respectively), $t(33) = -0.47$, $p = .64$, $d = 0.15$. In contrast, male participants were faster in completing the task when they interacted with the male (M = 5.13 sec., SD = 1.17) than with the female robot (M = 5.93 sec., SD = 1.32), $t(36) = 1.99$, $p = .055$, $d = 0.64$.

Errors. The 2 (*gender typicality of task*: Male vs. female) x 2 (*robot gender:* Male vs. female) x 2 (*participant gender*: Male vs. female) ANOVA revealed a significant main effect of *gender typicality of task,* $F(1, 65) = 3.97$, $p = .05$, $\eta^2 = .06$. That is, more errors occurred for the typically female (M = 0.11, SD = 0.08) than for the typically male task (M = 0.08, SD = 0.05). No other effects reached statistical significance, all *p*s > .46.

Alternatives. Results of a 2 (*robot gender:* Male vs. female) x 2 (*gender typicality of task*: Male vs. female) x 2 (*participant gender*: Male vs. female) ANOVA yielded a significant main effect of *participant gender*, $F(1, 65) = 13.63$, $p < .001$, $\eta^2 = .17$, indicating that female participants used alternative solutions more often instead of following the robot's instructions (M = 0.46, SD = 0.18) compared to male participants (M = 0.30, SD = 0.20). No other significant effects were found, all *p*s > .21.

3.3 Evaluation and Acceptance of the Robot

Robot evaluation. A 2 (*gender typicality of task*: Male vs. female) x 2 (*robot gender:* Male vs. female) x 2 (*participant gender*: Male vs. female) ANOVA revealed neither a significant main effect of experimental manipulation nor of participant gender, all *p*s > .50. However, we obtained a significant *gender typicality of task* by *robot gender*

[3] Note that the endpoints of the 7-point Likert scale were 1 = 'more female' vs. 7 = 'more male'. That is, values below 4 indicate that the robot was perceived as more female, whereas values above 4 show that participants perceived the robot as more male.

interaction effect, $F(1, 65) = 4.24$, $p = .04$, $\eta^2 = .06$. Further analyses showed that within the context of a female task, participants perceived the robot as equally competent, independently of whether the robot was ostensibly female ($M = 5.50$, $SD = 1.51$) or male ($M = 6.00$, $SD = 1.51$), $t(35) = 1.00$, $p = .32$, $d = 0.33$. However, when participants were instructed on a typically male task, they perceived the female robot as more competent ($M = 6.33$, $SD = 0.69$) than the male robot ($M = 5.56$, $SD = 1.33$), $t(34) = 2.22$, $p = .03$, $d = 0.73$.

Robot acceptance. Results of a 2 (*gender typicality of task*: Male vs. female) x 2 (*robot gender:* Male vs. female) x 2 (*participant gender*: Male vs. female) ANOVA yielded a main effect of *gender typicality of task,* $F(1, 64) = 5.31$, $p = .02$, $\eta^2 = .08$. Accordingly, participants were more willing to accept help from the robot on a future task when they previously interacted with the robot on a typically male task ($M = 4.89$, $SD = 1.85$) than when they worked on a female task ($M = 3.83$, $SD = 1.84$). No other main or interaction effect was significant, all ps > .24.

4 Discussion

Take a second again and imagine you could possess a robot that would assist you on any given task. However, this time, we would specify that you would get a female robot. For what kind of tasks should the robot ideally provide assistance? According to our findings, there is no simple answer to this question.

In the present experiment, female and male participants performed a stereotypically female or stereotypically male task while interacting with an ostensibly female or male robot. Thus, we tested the effects of gender typicality of an HRI task, robot gender and user gender on participants' performance during HRI and on the evaluation and acceptance of the target robot. With our experiment, we extended the previous literature on gender effects with respect to several aspects:

We tested for the first time the effects of such *gender typicality of the task* on HRI. By doing so, we demonstrated that gender typicality of the task the user and the robot completed together had substantial impact on the outcomes of the HRI: Participants made significantly more errors when performing a typically female task than a typically male task although both types of tasks were equally demanding. Moreover, when participants interacted with the robot in the context of a typically female work domain they were less willing to accept help from the robot in future tasks compared to participants who were instructed on a typically male task. Interacting with a robot in the context of a typically female 'work domain' thus resulted in less optimal outcomes than working on a 'male' task. However, the structure and ability requirements of both task types that we have used were equal, suggesting that the social role or stereotype that is attached to the different kinds of tasks has influenced how successful participants dealt with the task and the robot. Interestingly, many robots are developed to provide assistance on every-day tasks that are generally perceived as being typically female (e.g., providing assistance in the household). Accordingly, because our results indicate a more general problem with human–robot collaborations in 'female' domains, future studies need to address possible measures to counteract these difficulties and to make HRI on female-type tasks more efficient. However, prospective research should focus on further dependent measures to get a more differentiated picture of the effects of a task's gender typicality on HRI.

Furthermore, participants rated the robot's task competence differently, depending on the task's gender typicality and on the robot's alleged gender. That is, within the context of a stereotypically female task, the 'male' and the 'female' robot were perceived as equally competent. In contrast, for the typically male task the ostensibly female (vs. male) robot was evaluated as being more competent. This in part contradicts previous findings: Research has shown that a match between robot and task features, for instance in terms of humanlikeness, leads to greater human–robot acceptance [14]. Similarly, Eyssel and Hegel [8] have demonstrated that people prefer tasks for robots that match the gender of the robot. The present study, in contrast, yields evidence that partially speaks against a proper match of robot and task characteristics. To illustrate, when the robot gender and the gender typicality of the task were compatible, participants perceived the robot as *less* competent for the respective task, at least in context of a stereotypically male work domain. Comparing the present with previous findings shows that we should distinguish between factors that precede HRI and determine people's willingness to interact with a robot on the one hand, and factors that are key aspects of actual HRI and determine the success of an HRI, on the other hand. More specifically, a match between task and robot characteristics before an actual HRI takes place could be advantageous [8, 14]. According to our findings, *during* an actual HRI a mismatch seems to be beneficial as this indicates a higher competence of the robot. Future research needs to clarify under which circumstances and for which aspects such match or mismatch between task and robot characteristics is advantageous.

Above and beyond, our results add to previous findings that have shown that users react differently toward robots depending on their own gender [9, 17]. In the present study, female participants more frequently worked autonomously on the task and made their own choices instead of following the instructions of the robot (whereas the error rate remained unaffected by this) compared to male participants. This result possibly suggests that women might have less trust in robots then men. Additionally, male participants seemed to be more efficient (i.e., faster) when collaborating with a same-gender robot, whereas for women the robot's gender did not influence their velocity in performing the task. Interestingly, this is in line with previous research [11], indicating that men are more reactive to a robot's gender cues than women.

Taken together, our findings clearly point out that besides taking into account mental models users have about gendered robots [see 8, 17], we need to consider social roles and attributes that are related to traditionally male and female work domains when developing and designing robot systems. Many robot applications are related to societal gender roles. The present findings demonstrate for the first time that such 'gendered tasks' substantially influence how users perform during an HRI and how they perceive a robot's competence, specifically in the context of a female work domain. Thus, prospective research should focus on factors that could improve HRI for those applications that traditionally have been occupied by women.

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