Research Article Open Access

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Jealousy 4.0? An empirical study on jealousy-related discomfort of women evoked by other women and gynoid robots

https://doi.org/10.1515/pjbr-2018-0023
Received February 28, 2018; accepted September 21, 2018

Abstract: While first empirical studies on sexual aspects of human-robot interaction mostly focus on male users' acceptance, there is no empirical research on how females react to robotic replications of women. To empirically investigate whether robots can evoke the same kind of jealousy-related discomfort as do other women, we conducted an online study in which 848 heterosexual female participants from Germany reacted to the idea that their partner had sexual intercourse with either another woman, a human-like female-looking robot, or a machine-like female-looking robot. The results revealed dimensions in which the jealousy-related discomfort was higher for female competitors compared to the robotic ones (e.g., discomfort caused by the idea of sexual intercourse), whereas in others the robots evoked the same or higher levels of jealousy-related discomfort (e.g., discomfort caused by feelings of inadequacy, discomfort caused by shared emotional and time resources). The variance in the discomfort regarding sexual interactions between one's partner and robotic competitors could not be explained by personal characteristics (such as self-esteem, subjective physical attractiveness) but rather by technology-related variables (e.g., negative attitude towards robots, a tendency towards anthropomorphism) and the attitude towards sexual non-exclusivity in relationships. The study provides first empirical insights into a question which is of relevance for a responsible handling of sexualized technologies.

Keywords: jealousy, human-robot interaction, sex robots

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1 Introduction

Although from a basic understanding, robots are machines that help humans by executing programmed actions, they are more frequently used in interpersonal contexts [1]. While most robots are built to serve as assistants and companions (e.g., in healthcare or for learning tasks), one emerging field of application is the usage of human-like robots for the fulfillment of sexual needs. First companies, such as Realbotix, are working on making sex robots commercially available by equipping sex dolls both with motors to make them move and with speakers to create the impression of communicative ability [2]. The robotic replications of women have been widely discussed among scientists and journalists alike (e.g., [3–6]). While some see potential benefits for the sex lives of, for instance, people with disabilities, people suffering from social anxieties or people who do not participate in sexual activities on a regular basis (e.g., because they do not have a partner) [4, 7], others warn about potential negative consequences for both men and women [5, 8] (see section 2.1 for details).

However, the normative discussion about sexualized robots mostly lacks empirical evidence, and the few empirical studies in the field of intimate interactions among humans and robots mainly focus on men's reactions to these sexualized robots (e.g., [9]). Research on the question of how women perceive these robotic replications which are specifically built to enable sexual intercourse is lacking even though academia is aware that the technology of sexualized robots is accompanied with concerns regarding a responsible handling. In a paper discussing machine ethics, Bendel asked whether it is "…possible to be unfaithful to the human love partner with a sex robot, and can a man or a woman be jealous because of the robot's other love affairs?" [10, p. 24]. In this line, the present study aims to empirically investigate whether women perceive robots as potential competitors to their relationship in the same way as they perceive other women to be so. As the degree of human-likeness of robots contributes to the similarity between female-looking robots

and women, we additionally investigated differences between machine-like female-looking robots and human-like female-looking robots with respect to their ability to evoke jealousy-related discomfort. Furthermore, we examined whether different personality traits and attitudes towards technology are associated with the evoked discomfort regarding the imagined sexual interaction between a partner and a robot. The question of whether robots can evoke jealousy-related discomfort in women is important, as it reflects women's feelings about mechanical replications of them. Moreover, answers to this question can provide first empirical insights into potential consequences for owners' social environment. As such, we wish to contribute to the understanding of human reactions to robots. While we are interested in learning about human experiences by means of empirical research and do not take a normative stance, our results should be able to foster responsible robotics research.

2 Literature review

2.1 Representation of sexuality in robots

Based on the current state of technological developments, robots do not have a biological sex [11]. Scholars like Haraway have discussed cyborgs as an opportunity to leave gender-related inequalities behind and create a new form of identity [12]. However, other researchers have highlighted that this ideal might be hard to achieve as long as humans decide on what robots should look like (e.g., [11, 13]). Søraa noted in this regard that "A robot is perhaps perceived as a gendered tabula rasa actor in this world of extreme gender discussion – the genderless robot. However, this tabula rasa state is not achievable when a robot is constructed by humans, as the robot's design is affected by the human creator's belief in what gender the robot 'does' and 'does not' perform." [11, p. 103]. Given that there are more males working in computer science, engineering, and robotics this might be dangerous, especially because "Most gendered humanoid robots currently being developed with a realistic human appearance are female." [14, p. 53].

Critics of the technology have therefore already pointed out that this gender bias might lead to replications of males' stereotypes of women in terms of robots' behavior and appearance (e.g., wearing tight clothing which strongly accentuate the breasts and/or buttocks as is already observable in science fiction movies) [8, 14]. Due to such concerns, Kathleen Richardson founded the Campaign Against Sex Robots [5, 8]. In the policy report for the campaign (from the website), she stated that sexualized robots can negatively affect the societal standing of females by enhancing mechanisms of objectification or the "dehumanization of women in pornography and prostitution".

However, human-like cues of machines are important with respect to their acceptance and usefulness [15] and it is likely that this will also be the case regarding sexualized interaction. The developer David Hanson explained that "if we want to develop robots that would best support us, it would be better to make them as much as possible a replica of our shape, average size, and ability" [1, pp. 15-16]. The consequence of replicating specific visual characteristics of humans is that robots are equipped with cues that are societally associated with a specific gender [13]. First prototypes of sexualized robots, for instance by Realbotix [2], now provide sexuality-related details which would not be necessary with other robots. In an interview held during a scientific conference on human-robot interaction (HRI), Matthew McMullen, CEO of a company working on robots built to fulfill sexual needs, stated that 80% of the so-called sex dolls (seen as the predecessor of sex robots) that his company creates represent the female sex and that 80% of the customers are male [16]. Thus, it can be assumed that female-looking sexualized dolls and robots are mostly used to replicate heterosexual intercourse and/or heterosexual relationships. Based on the strong representation of sexuality, we argue that sex robots have the potential to be perceived as a third actor influencing the dynamics of existing long-term relationships between humans and can therefore pose a threat to these relationships.

2.2 Psychological jealousy models in the context of human-robot interaction

There is empirical evidence that technology use in terms of computer-mediated communication (e.g., Facebook) can enhance jealousy between two people in a romantic relationship [17]. However, there is no research on whether the technology itself can be perceived as a source of jealousy. Therefore, no model exists to describe the psychological mechanisms involved when a person experiences his/her partner engaging in sexual intercourse with a machine, and it is necessary to apply models from human-human interaction to the context of human-robot interaction. In the present paper, we take the perspective of the person who fears being betrayed, and therefore adopt the concept of romantic jealousy. Romantic jealousy is defined as a "com-

plex of thoughts, emotions, and actions" caused by a realistic or imaginary rival that "threatens the existence or quality of the romantic relationship" [18, p. 9]. Jealousy in romantic relationships is an interplay of thoughts, behaviors and affects between three parties, i.e. the jealous, the beloved and the rival. We argue that robots do have the potential to be perceived as a third actor within the dynamics of a long-term relationship between two people (see section 2.1 for details).

The first component of the romantic jealousy model is primary appraisal/reappraisal, meaning that the jealous person reflects upon the potential threat to the self and the relationship of the imagined or actual rival. The role of imagination in romantic jealousy is worthy of consideration when analyzing the possibility of feeling jealous of a machine. As robots are not yet everyday interaction partners, people tend to gather their information about robots from movies [19]. Those movies do not only belong to the genre of science fiction, but moreover, the displayed robots are mostly animated and/or portrayed by human actors. Consequently, the presented "machines" do not reflect the state-of-the-art in robotics [20]. However, based on the image of robots provided by mass media people could gain the impression that robots are not only able to move flawlessly and to take part in a fluent conversation, but that they are also programmable and consequently correspond to every desire of the user. In reality, the development of a human-like robot, which is capable of not only performing flawless movements, but also reacts towards movements and has basic intelligence, is very complex. This is why, for the moment, it is only possible to purchase a robot that is composed of a motionless body combined with a robotic head that has the capability to communicate simple sentences and show facial movements [16]. However, as laypersons usually do not have an overview about current technological developments [19], their unrealistic expectations might stimulate jealousy to the extent that robots are seen as flawless, problem-free partners.

The secondary appraisal of the romantic jealousy model is the evaluation of information the jealous person has about him/herself, about the potential/actual rival, and about possible motives of the partner. One aspect of this evaluation is the social comparison with the rival. On the one hand, the nature of the comparison itself (human vs. robot) might lead to a positive evaluation of the self in terms of not being a mechanical replication. While technological developments will make it possible to equip robots with very human-like appearances and behaviors, it is unlikely that robots built to fulfill sexual needs will be able to perfectly replicate interpersonal communication or aspects of romantic relationships between humans, such as self-disclosure (for instance, robots cannot tell a true story about their past or opening up about problems [20]). On the other hand, the completely controllable appearance and behavior of the robot might lead to a negative evaluation of the self and of one's body, which has been found to decrease self-esteem within humans [21]. In times of rapid advances in hardware and software development, robots can be equipped with numerous behavioral and appearance-related attributes, which make them customizable and therefore likely to match the current beauty ideals. Conceivably, this might also contribute to the feeling of jealousy, as studies revealed, for instance, that people with a low waist-to-hip ratio evoked more jealousy [22]. Another aspect of the category of secondary appraisal is the reflection of the possible motives of the partner. If a person's partner chooses to have sexual intercourse with a robot, the person may reflect about the partner's sexual norms. Even though technologies are being increasingly incorporated into sexual activities (e.g., the use of a vibrator in sexual interactions), having sexual relations with a human-shaped robot deviates from statistical sexual norms [23].

The third main category of the romantic jealousy model comprises the evoked, mostly negative emotions, such as anger, sadness, envy, or guilt. Although some studies have investigated the potential of robots to evoke certain emotions (e.g., embarrassment [24]), most studies in HRI focus on the evaluation of the robots themselves. To date, no studies have examined the potential of robots to evoke emotions connected to jealousy.

The final main category of the romantic jealousy model encompasses the coping effects, such as improving the relationship or demanding commitment. However, as these are specific reactions to a partner's infidelity and are more focused on the behaviors of the jealous person, this category is neglected in the context of the present study.

2.3 Evolutionary perspective on sexual competitors

When focusing on the person experiencing jealousy, a further applicable model has its roots in an evolutionary perspective. Although interacting with robots is a new phenomenon, people's perceptions and anxieties regarding robots might be influenced by their biologically rooted tendencies regarding threats to their relationships. Based on an evolutionary perspective, it can be argued that robots should not pose a threat to women – due to a robots' lack of ability to become pregnant and the resulting shared resources. Although jealousy is not linked to survival per

se, it is connected to reproductive success, as it helps to maintain relationships by motivating behavior that aims to avert threats [25]. Following the evolutionary perspective, these threats differ for men and women: While men fear parental uncertainty if their partner engages in sexual interactions with other men, women are mainly worried about shared resources, meaning not only the time, money and emotions shared with the other partner, but also their potential offspring [25, 26]. Studies have revealed that women feel greater discomfort when they think about their partner becoming emotionally attached to another woman compared to when they think about their partner only engaging in sexual relations with another woman (e.g., [27]). In contrast to other women, robots are not able to pose a threat in terms of potential offspring with a woman's romantic partner. Nevertheless, robots might cause discomfort regarding shared financial resources (e.g., the costs of the robot itself, warranties) and regarding shared emotional resources (e.g., spending time together). Therefore, robots do, in theory, have the potential to evoke jealousy even from an evolutionary psychological perspective. However, the intensity of the usage, meaning whether the partner spends time and shares emotions with the machine rather than only using the robot for sexual fulfillment, is also likely to contribute to the evoked jealousy.

2.4 Gynoid robots: influence of appearance on jealousy

Based on sociological definitions of sexual deviance [19], it can be assumed that the human-like appearance of robots plays an important role in intimate interactions between humans and robots. For example, it would be awkward to engage in sexual interactions with something that resembles a machine rather than a human. For women, it is conceivable that the visual similarity contributes to the tendency to compare themselves with the robot. This, in turn, might affect whether women engage in social comparisons with their robotic replications, as studies have found that women tend to compare their appearance to that of other women whom they perceive as having similar or better body qualities [28]. The jealousy is also influenced by the potential reactions of the partner to the competitor [18]. Regarding the effect of robots' appearance on heterosexual men, it can be speculated that the visual similarity with women will increase the feeling of sexual norm adherence, as having sexual intercourse with a nonliving object deviates from sexual norms [19]. Moreover, more detailed human-like gynoid robots provide visual information, such as hair or skin, which also signals beauty and health [26]. This probably also contributes positively to males' acceptance of sexualized robots. First empirical studies demonstrated that, if asked explicitly, men indeed evaluated human-like gynoid robots as more attractive than machine-like gynoid robots [9].

On the other hand, it is also conceivable that sex robots do not need to look like detailed replications of humans in order to evoke jealousy-related discomfort in women. This would be in line with different empirical studies which showed that the use of phallus-shaped sex toys (vibrators or dildos) caused uncomfortable social situations in long-term relationships [29, 30]. Fahs and Swank conducted interviews with twenty women who used vibrators and found out that "women worried that their partners would not automatically feel superior to a machine and that disclosure of sex toy use would undermine hegemonic masculinity notions of men's (inherent) sexual mastery" [30, p. 676]. However, it is unclear whether these concerns are also confirmed by men themselves, as to our knowledge, only one study has provided statistics on men's acceptance of their female partners' use of phallus-shaped sex toys. In the study, 30% of the 1047 men (aged 18-60 years) indicated that it would be intimidating if their partner used a vibrator [31]. Another - but closely related - aspect of why the human-like appearance of sex robots might play a less important role for the jealousy-related discomfort evoked by sex robots is that sexuality is driven by fantasy in any case [32]. Accordingly, men, as well as women, might see something different, potentially something more human, in the obvious machine.

2.5 Hypotheses

Differences in jealousy-related discomfort based on the nature of the competitor

The present study aims to investigate whether there are differences between the jealousy-related discomfort of females evoked by other women and that evoked by human-like and machine-like gynoid robots. As jealousy is a multifaceted construct, encompassing different reasons for reactions of discomfort (see section 2.2 for details), we use "jealousy-related discomfort" as an umbrella term for the various aspects of jealousy we aim to investigate. Since a) women are familiar with feelings of jealousy towards other women and b) from an evolutionary perspective, other women pose a threat to their reproductive success while robots do not, we assume that women create stronger levels of jealousy-related discomfort than do robots. However, as robots can be built to appear more or

less human-like, we also investigate potential differences between human-like and machine-like gynoid robots. Although the literature suggests that people tend to fantasize during sexual intercourse and can also anthropomorphize objects that are obviously non-living entities (see section 2.3 for details), it can be assumed that the higher comparability between human-like gynoid robots and women will lead to higher levels of jealousy-related discomfort towards human-like compared to machine-like gynoid robots. Therefore, we propose the following hypothesis:

H1: The nature of the competitor has an influence on the evoked jealousy-related discomfort of women: Other women evoke the highest level of jealousy-related discomfort (in its different aspects), followed by human-like gynoid robots, while machine-like gynoid robots evoke the lowest level of jealousy-related discomfort.

Influence of personal characteristics and technology-related variables on discomfort regarding sexual interaction with a robot

We further aimed to examine whether personal characteristics or attitudes towards technology can explain the variance in the discomfort evoked by the imagined sexual contact between one's partner and a female-looking robot.

With regard to personal characteristics, social comparison is, according to the literature, a part of jealousy, which in turn is related to the personal characteristics of self-esteem and subjective physical attractiveness [21, 22]. Therefore, both variables were included in the present study as potential predictors for the discomfort evoked by the imagined sexual interaction with a robot. Moreover, the attitude towards non-exclusivity in romantic relationships is of interest, as it describes whether participants will use the same standard for robots which they would apply to a human partner.

Furthermore, attitudes towards technology might also explain why women become jealous of a robot. In this regard, negative attitudes towards robots and the tendency to anthropomorphize technology might be important [33]. Robots are machines, and as there are already some technological devices which can be incorporated into sexual interactions (e.g., vibrators), it can be assumed that the openness to technology in sexual interactions is a further important variable regarding the jealousy evoked by robots. Based on these assumptions, we ask:

RQ1: How much of the variance in the jealousy-related discomfort caused by the partner's sexual interaction with a robot can be explained by women's personal characteristics (self-esteem, subjective physical appearance, attitude towards non-exclusivity) and by attitudes towards technology (negative attitudes towards robots, tendency towards anthropomorphism, and openness to technology in sexual interactions)?

3 Method

3.1 Participants and procedure

To investigate whether there are differences in the jealousy-related discomfort evoked when confronted with the idea that one's partner engages in sexual interactions with either another woman, a human-like gynoid robot or a machine-like gynoid robot, a total of 848 German heterosexual women aged 18-63 years (M = 25.43, SD = 6.51) were recruited to participate in an online survey. One of the advantages of a web-based experiment lies in the larger sample size, which positively influences the external validity of the results [34]. Moreover, as there is no convincing sex robot available yet which might have been presented to the participants as a potential competitor, there was no reason to invite the participants to the laboratory. 619 (73%) of the 848 participants indicated being in a long-term relationship at the time of the study. Inclusion criteria were female gender, age 18 or over, and being heterosexual; these were explained on the front page of the survey and needed to be confirmed before continuing the survey. Participation was voluntary, and participants were free to exit the questionnaire at any time. Participants were recruited nationwide via postings in various Facebook groups, and they had the chance to win a gift certificate.

To avoid carry-over effects between the reactions to the different groups of competitors, the study employed a between-subjects design with three groups: In the first group, participants were asked to imagine that their partner had sex with another woman (N = 287); in the second group, participants were asked to imagine that their partner had sex with a female-looking human-like gynoid robot (N = 287); and in the third group, participants were asked to imagine that their partner had sex with a machine-like gynoid robot (N = 274). The procedure was similar across the groups. The women were first asked to answer some questions about themselves, before participating in the thought experiment, in which they imagined that they had found out that their partner had sex with either another woman, a human-like gynoid robot, or a machine-like gynoid robot. Thought experiments are a frequently used method in jealousy research (e.g., [27]).

To ensure the comparability of the groups, all participants were shown a picture of four potential competitors matching their group (e.g., a picture showing four human-like gynoid sex robots). Examples from each stimuli group are provided in Figure 1. The displayed women as well the human-like robots were only covered by underwear to make it easier for the participants to imagine a sexualized interaction (especially in contrast to other clothing, e.g., business clothing). The machine-like robots did not wear any underwear because it would not make sense to cover up mechanical parts as they lack human-like details such as skin. By showing four different stimuli in each category, it was ensured that all participants had the same idea of the possible threat they had to think about. Moreover, effects did not rely merely on participants' imagination but were also caused by the specific appearance of a single stimulus. There was one difference between the questionnaires of the other-woman group and the two robot competitor groups: The participants in the robot competitor groups had to watch a short video clip showing state-of-the-art robots in order to familiarize them with the appearance and abilities of robots (e.g., stand, walk, talk, display nonverbal cues), as most people's understanding of robots is based on movies [19].

Figure 1: Examples of the stimulus material of the groups: women (left), human-like gynoid robots (middle), machine-like gynoid robots (right).

After completing the survey, participants were informed about the purpose of the study and received the contact details of the principal investigator, whom they were encouraged to contact if they had any additional comments or questions. To meet the standards of ethical acceptability of psychological research, the study was approved by the university's ethics committee prior to data collection.

3.2 Measurements

In the following, it is explained how jealousy, attitudes towards technology, and personal characteristics were measured. All questions were answered on a five-point Likert scale ranging from 1 = *disagree* strongly to 5 = *agree strongly*.

3.2.1 Jealousy-related discomfort

As explained above, jealousy is a complex, multidimensional construct, which is accompanied by feelings of incompetence, weakness, and discomfort [18]. Therefore, we aimed to cover different aspects of jealousy-related discomfort based on the literature review. In the literature, we found different reasons for jealousy, defined as the discomfort based on shared resources, such as shared sexual resources, financial resources, and emotional resources (e.g., spending time together, sharing attention). Sharing the resources of one's partner with another person constitutes a threat to the exclusivity of a romantic relationship [18, 25]. Therefore, we included this subdimension of jealousy in the present study. Moreover, we found several outcomes, such as negative emotional consequences and the comparison between the jealous person and the opponent, which we also included in the measurement [18, 22, 25, 26, 28].

To our knowledge, there was no previously existing scale which covers all of these aspects and is also suitable to be adapted to the purpose of the present study. Therefore, it was necessary to develop a measure that not only evaluates different important aspects of jealousy but that can also be used for both the female and the robotic competitors. We developed a scale comprising a total of 30 items. To reduce the number of items and to examine the structure of the scale, we conducted an exploratory factor analysis with principal component analysis and varimax rotation, followed by Horn's parallel analysis. This yielded three main factors based on the eigenvalue criteria. An additional exploratory factor analysis with principal axis analysis and promax rotation revealed the factor loadings for each item. All items with factor loadings lower than .50 and/or parallel loadings higher than .20 were excluded from the analysis [35]. Based on the theoretical background of some items, we conducted additional exploratory factor analyses to reveal potential subdimensions in the factors "sharing of resources" and "personal negative consequences". All subdimensions are explained in the following. Please note that the remarks in square

brackets indicate the different versions of the questionnaire.

3.2.2 Jealousy-related discomfort: discomfort regarding sexual contact (Factor 1)

This aspect refers to the discomfort caused by the sexual interaction of one's partner with the competitors and the violation of sexual norms (regarding a robotic opponent [23]). The exploratory factor analysis for the items yielded a factor with three items (e.g., "I would feel uneasy if my partner preferred to participate in certain sexual activities with [another woman/ a human-like gynoid robot/ a machine-like gynoid robot] rather than with me" or "It would bother me to know that my partner fulfills some of his sexual needs with [another woman/ a human-like gynoid robot/ a machine-like gynoid robot]"). The scale had an internal consistency of α =. 80.

3.2.3 Jealousy-related discomfort: sharing of resources (Factor 2)

The additional exploratory factor analysis revealed that the six items could be assigned to two subdimensions; a) the discomfort based on sharing emotional and time resources and b) the discomfort based on sharing financial resources. The first subscale consists of four items, such as "It would bother me if my partner fell asleep with [another woman/ a human-like gynoid robot/ a machine-like gynoid robot] or "It would bother me to know that my partner spends time with [another woman/ a human-like gynoid robot/ a machine-like gynoid robot]". The scale had an internal consistency of α =. 66. The second subscale is composed of two items and had an internal consistency of α =. 71. An example item is: "It would bother me to know that my partner spend money on [another woman/a human-like gynoid robot/a machine-like gynoid robot]".

3.2.4 Jealousy-related discomfort: personal negative consequences (Factor 3)

Jealousy causes negative emotions and negative evaluations of the self in comparison to the competitor [18]. The exploratory factor analysis revealed that the scale measuring the negative consequences for one's partner having sexual interactions with another woman or a robot could be divided into two subdimensions: the feeling of inadequacy and the evoked negative emotions. The first subscale, measuring the feeling inadequacy as a consequence of infidelity with another woman or a robot and the resulting negative self-evaluation, consists of the three items "If my partner had sex with [another woman/a human-like gynoid robot/a machine-like gynoid robot], I would ask myself whether I'm attractive enough", "I would blame myself if my partner had sex with [another woman/a human-like gynoid robot/a machine-like gynoid robot]" or "If my partner had sex with [another woman/a human-like gynoid robot/a machine-like gynoid robot], I would feel inadequate and ask myself what he sees in [her/it]." The Cronbach's alpha was α =. 77. The second subscale measures negative emotions evoked by the thought of one's partner having sexual interactions with another woman or a robot. It comprises seven items, such as "I would feel hurt if my partner had sex with [another woman/a human-like gynoid robot/a machine-like gynoid robot]" or "I would be angry if my partner had sex with [another woman/a human-like gynoid robot/a machine-like gynoid robot]". The internal consistency was α =. 94.

3.2.5 Self-esteem (personal characteristic)

The German version of the Rosenberg Self-Esteem Scale was used to assess the individual level of self-esteem [36]. The scale comprises ten items (e.g., "I feel that I have a number of good qualities" or "I have a positive attitude towards myself"). The internal consistency was α = .91.

3.2.6 Physical attractiveness (personal characteristic)

The Physical Attractiveness Subscale of the Physical Self-Concept scale by Stiller, Würth, and Alfermann was used to measure participants' subjective physical attractiveness [37]. The subscale consists of 10 items, such as "I feel confident in my body" or "I am proud of my body", and had an internal consistency of α =. 91.

3.2.7 Sexual non-exclusivity (personal characteristic)

The attitude towards sexual exclusivity in long-term relationships was assessed using a translated version of the sexual non-exclusivity subscale of the Relationship Issue Scale by Boekhout [38].The scale had an internal consistency of α =. 85 and is composed of seven items, such as "Having sex with someone other than one's primary partner is a threat to relationship intimacy/stability" or "I con-

sider it as infidelity if one has sex with somebody else than one's primary partner".

3.2.8 Negative attitudes towards robots (attitude towards technology)

The German version of the Negative Attitudes towards Robots Scale by Nomura, Suzuki, Kanda, and Kato was used to measure whether participants have a negative mindset regarding robots [33]. The scale consists of 14 items (e.g., "I would feel paranoid talking with a robot" or "I would feel uneasy if robots had real feelings") and had an internal consistency of α =. 79.

3.2.9 Anthropomorphism (attitude towards technology)

The "tendency to ascribe human characteristics to non-human objects" was measured by nine items (e.g., "I can see why people name their cars or computers" or "I have experienced that some of my electronical devices (e.g., smartphone or computer) refused to cooperate."), which were derived from the German version of the Anthropomorphism Questionnaire by Neave, Jackson, Saxton, and Hönekopp [39, p. 214]. The internal consistency was α = .71.

3.2.10 Openness to technology in sexual interactions (attitude towards technology)

We developed a scale to measure how open-minded the participants were regarding the usage of technology in sexual interactions. For this purpose, we searched for different new sexualized technologies in different online stores. The five items encompass different scenarios with technological sex toys, such as "The thought of using a smartphone application to control sex toys is exciting for me" or "If I could, I would watch virtual reality porn together with my partner". The internal consistency was α = 67.

4 Results

4.1 Differences in women's jealousy-related discomfort caused by other women and by female-looking robots (H1)

To examine potential differences in the different dimensions of jealousy-related discomfort caused by either another woman or by robots, a MANOVA was conducted. The results revealed a statistically significant difference in the different aspects of jealousy-related discomfort based on the nature of the competitor (human, human-like gynoid robot or machine-like gynoid robot) (F(10, 1682) = 12.03, p <.001, *Wilks'* Λ = .87, partial $\eta 2$ = .07). The pairwise comparisons revealed that the discomfort caused by the idea of the partner's sexual intercourse with a competitor, the discomfort caused by shared financial resources, and the negative emotional consequences were higher for a female competitor compared to the robotic competitors. The evoked jealousy-related discomfort did not differ between the human-like gynoid robot and the machine-like gynoid robot. The opposite was the case for shared emotional resources: Here, the robots evoked a higher level of discomfort than the women. The only aspect of jealousy-related discomfort on which the nature of the competitor had no significant effect was the feeling of inadequacy (p = .568). Table 1 shows all means and significant differences.

4.2 Explained variance in discomfort caused by sexual interaction with a robot (RQ1)

To determine how much of the variance in the jealousy-related discomfort based on sexual interactions with a robot can be explained by personal characteristics or the attitude towards technology, a hierarchical multiple regression analysis was computed. Since the results of H1 revealed no significant difference between the machine-like and the human-like gynoid robot regarding the evoked discomfort, the data of both groups were entered into the regression. The personal characteristics self-esteem, subjective physical attractiveness, and attitude towards non-exclusivity were inserted in the first block. The negative attitude towards robots, the tendency to anthropomorphize, and the openness to the usage of technology in sexual interactions were combined in the second block, presenting the technology-related variables. The first block explained 25.2% of the variance (F(3,557) = 62.54, p < .001), and the second block explained an additional 6.1% (F(6,554) = 42.11, p < .001). The coefficients of the full model revealed that only the attitude towards sexual non-exclusivity in relationships (β = -.42, p < .001), the negative attitude towards robots (β = .19, p < .001), and the openness to technology (β = -.15, p < .001) emerged as significant predictors of the discomfort caused by the partner's sexual interaction with a robot. Thus, the jealousy-related discomfort caused by an imagined sexual interaction with robots can be partly explained by these three factors.

Table 1: Means and significant differences of the jealousy aspects.
Note. Means in column-sharing subscripts are significantly different from each other.

Aspect of jealousy	Woman	Human-like gynoid	Machine-like gynoid
Discomfort caused by idea of sexual intercourse			
M	$4.63_{a,b,c}$	$4.38_{a,b}$	$4.39_{a,c}$
SD	0.79	0.87	0.87
Discomfort caused by shared emotional and time resources			
M	$4.03_{a,b,c}$	$4.22_{a,b}$	$4.23_{a,c}$
SD	0.82	0.86	0.76
Discomfort caused by shared financial resources			
M	$4.52_{a,b,c}$	$4.27_{a,b}$	$4.23_{a,c}$
SD	0.75	0.99	1.04
Feeling of inadequacy			
M	3.80	3.71	3.72
SD	1.06	1.13	1.10
Negative emotional consequences			
M	$4.59_{a,b,c}$	$4.01_{a,b}$	$4.19_{a,c}$
SD	0.86	1.06	0.96

5 Discussion

5.1 Differences in jealousy-related discomfort caused by women and female-looking robots

The results of the present study showed that the discomfort caused by sexual interactions of women's long-term partner was higher in the case of a female competitor than in the case of robotic competitors. On the one hand, this finding may be attributable to the fact that the thought of sexual interactions between one's partner and robots might still be too abstract. On the other hand, it is conceivable that women equate sexual interactions with sex robots with "meaningless one-night stands" especially as it seems unlikely that their partner will engage in more than sex (e.g., conversations about feelings). According to Buss, one-night stands are easier for women to get over compared to relationships with other women. In such relationships, it is more likely that the partner will reduce the resources which were originally exclusive [25]. The result, moreover, potentially underlines the importance of the biological background of the competitors.

It is conceivable that the imagined sexual interaction with a woman caused more discomfort than the imagined sexual interaction with a robot because there is no chance that the robots could produce offspring, which, from an evolutionary psychological perspective, would be the main reason for jealousy among humans as it comes along with shared resources (e.g., time resources, emotional, financial resources) [26].

In this respect, additional qualitative research needs to be conducted to gain insights into women's understanding of sexualized robots. Moreover, further research needs to answer the question whether sexual interactions with robots are comparable to sexual interactions with other human beings or more strongly comparable to sexual interactions with sex toys (e.g., vibrators).

Contrary to our prediction, the discomfort caused by shared emotional and time resources was higher for both robotic conditions than for the female competitor. It is known that women suffer more if their partner has an emotional attachment to another woman compared to an emotionally meaningless one-night stand [27, 37]. If the partner had an emotional attachment to a female-looking robot, this would not only mean that the partner chooses another interaction partner to share his thoughts and attention with, but also that he chooses a robotic replication over the woman herself. While sex robots are built for sexual interactions, the comparison of the woman to a robot regarding the ability to share emotions and time could lead to a more negative evaluation of the self (for instance that

the machine is a better listener) or of the partner. Additionally, if a woman's partner is sharing emotional and time resources with a non-living human-like entity, she may gain the impression that her partner deviates from social norms.

The discomfort caused by shared financial resources was higher with regard to women than the robotic competitors, which might be caused by their higher similarity. While financial resources used on another woman could be equally spent on a man's own partner (e.g., buying the same gifts for the female opponent), the robot would require the man to spend money on things like a warranty.

The negative emotional consequences (e.g., the feelings of anger or sadness) were higher regarding the female opponents compared to the robotic opponents. It is possible that the participants in the robotic conditions could not imagine feeling strong emotions like anger towards a machine, whereas the women in the female opponent condition were familiar with the concept of other women evoking such emotions. However, more research needs to be conducted to understand the underlying processes.

Surprisingly, the results showed that robots can evoke the same feeling of inadequacy that can be evoked by other women. This is of special interest, as it was the only subdimension to focus on how the participants perceived themselves after imagining their partner having sexual interactions with another woman or a robot. Evidently, the women did not see themselves as having advantages over their robotic replications, and were therefore as affected by the robots as they were by the imagined contact of their partner with other women. While women need to gather some information on their human competitor and reflect on dimensions in which the opponent may have an advantage [18], robots can be built and programmed to perfectly match the partner's preferences in terms of behavior and appearance. Moreover, people's beliefs about robots are strongly influenced by movies [19], in which female-looking robots not only have emotional intelligence (e.g., Ex Machina) but are also built to satisfy sexual needs (e.g., Westworld) [40, 41]. It is possible that a broader technological understanding and a new form of technology-related self-confidence might be beneficial for women in order to better comprehend the positive and negative potential of upcoming technological developments, such as sexualized robots. Such reinforcement of women who understand, work on, and shape technological developments is in line with the concept of cyberfeminism [42, 43]. One may intuitively argue that sexualized robots particularly contradict the concept of cyberfeminism, because they reinforce the male dominance in the creation of technology that is made by and for male users (especially with regard to female-looking robots) and underline differences between what men and women want [44]. However, robots do have the potential to help people act out their sexual preferences regardless of societal boundaries of gender or norms. In this respect, female developers will also be important in order to create sexualized technologies which respect and represent female needs.

Overall, it needs to be highlighted that, according to our findings, the design of a robot as either human-like or machine-like was not as important as assumed. Although the human-like robots provided more and detailed human-like visual cues, which could have led to a higher comparability between the women and the robot, the results showed that the female body shape of a robotic competitor is sufficient to trigger feelings of discomfort in women. However, it might be assumed that the processes underlying the discomfort differed between the human-like and machine-like robots. For instance, the appearance of the machine-like gynoid robots might have caused discomfort because this would signify that the partner would be violating sexual norms. Qualitative research also needs to be conducted in this regard to determine how women perceive the threat of different female-looking robots.

One implication of these findings is that robots do have the potential to negatively affect the owner's romantic relationship with another human being. Scientists have made various attempts to define rules or guidelines that would lead to ethical or responsible actions of robots [45, 46]. Some of these approaches include the social environment as an important influence on this evaluation. For instance, Gips focused on the potential consequences of an action as an elaborative principle. He stated: "Thus to reason ethically along consequentialist lines a robot would need to generate a list of possible actions and then evaluate the situation caused by each action according to the sum of good or bad caused to persons by the action. The robot would select the action that causes the greatest good in the world." [47, pp. 246-247]. Based on the present findings, this would mean that (according to their computational abilities), in order to act ethically, sex robots would also need to elaborate on whether a sexual interaction would cause negative consequences for the owner and his or her social environment. Fulfilling the sexual needs of the owner might not only psychologically hurt the owner's partner but might also lead to negative consequences for the owner him/herself, if the intimate interaction causes serious relationship issues with the human partner. Designers of robots that are intended to fulfill sexual needs should therefore be aware that by following the implemented behavior, robots can cause negative social conse-

quences for users in long-term relationships with other humans.

5.2 Explained variance in discomfort caused by sexual interaction with a robot (RQ1)

The attitude towards non-exclusivity was the only personal characteristic that explained variance in the discomfort caused by the partner's sexual interaction with a robot. At the same time, it was the strongest significant predictor of all included variables. On the one hand, this is contrary to our prediction, as we assumed that self-esteem and subjective physical attractiveness would also contribute to the feeling of discomfort when a partner chooses to have sexual interaction with a robot over the actual partner. Nevertheless, we specifically included this variable to demonstrate that values of long-term relationships can also be transferred to the context of HRI. More research is necessary to define infidelity with a robot. Moreover, the results showed that the measurement of negative attitudes towards robots, which is frequently used in HRI research, also plays a role in sexual interactions with robots. It is plausible that women react with more discomfort in response to the idea of their partner having sexual interactions with a robot if they have a negative attitude towards robots in general. The finding is moreover in line with Szczuka and Krämer who revealed that the negative attitude towards robots is a negative predictor of how sexually attractive robots are perceived [9]. The results therefore underline the importance of this variable regarding sexualized interactions with human-shaped machines. The analysis also demonstrated that the more women interact with technology in intimate situations, the less discomfort they feel when imagining their partner having sexual interactions with a robot. This again seems plausible, as robots can also be categorized as technology. However, it is possible that the human shape of this technology contributed to its small explanatory value, as people are not yet used to this type of technology. Even though the predictor was not as strong, this variable might be of interest for future research, as technology and its meaning will change over time [19]. The growing acceptance of technology in sexual interactions can also be observed in the increasing number of commercially available electronic devices, ranging from vibrators that can be controlled via smartphone applications to virtual reality porn [48, 49].

5.3 Limitations and future studies

As the present study attempted to cover new ground in the research of sexual interactions with robots, it is not without limitations. It could be argued that the results of the thought experiment are not comparable with real experiences. Presumably, many of the women who took part in the study were thinking about potential robotic competitors for the first time. The idea of sexual interactions with robots may therefore have been strongly influenced by their previous knowledge of robots, which is often heavily influenced by movies, such as Ex Machina [40] (https://www.imdb.com/title/tt0470752/) or Blade Runner [50] (https://www.imdb.com/title/tt0083658/?ref_=nv_sr_2). The human-like gynoid robots depicted in these movies have abilities in terms of movement, appearance, and moral judgments which will not realistically be implemented in real robots within the next few years [19]. However, we aimed to counterbalance this limitation by showing the participants videos about the ability of state-of-the-art robots (see method section for details). Moreover, we did not incorporate a trait jealousy scale to control for the extent to which the participants tend to be jealous in general.

The study represents a first attempt to empirically investigate the influence which sex robots may have on long-term relationships. To gain a broader understanding of jealousy in interactions between humans and machines, future research needs to a) define cheating in the context of human-robot interaction, b) determine the influence of the customization of the robots' appearance and behavior on the jealousy they might evoke, and c) explore the changing attitudes towards technologies which are used in sexual interactions.

It is noteworthy that the present study did not find differences in the jealousy and discomfort caused by the idea of a partner having sexual interactions with a human-like or a machine-like robot. This suggests that gynoid robots do not even need to look like exact replications of humans to cause negative effects regarding the relationship and the self. Similar results were also found in men with regard to vibrators [30]. Future studies should therefore incorporate even less human-like technologies (e.g., artificial vagina/fleshlight) to gain more knowledge on the importance of human-like visual cues for jealousy in human-machine interactions.

Future studies should also incorporate the cultural background of the participants as one potentially important determinant of the reactions to robotic romantic competitors. As Asian countries, such as Japan, were found to have incorporated robots more strongly into their culture,

different studies aimed to investigate the influence of culture on reactions towards robots [51, 52]. Thus, intercultural empirical research is needed to determine whether cultural background will enhance or reduce jealousy-related discomfort as a reaction to robotic romantic competitors.

As female-looking robots might not only be perceived as rivals, but may also have the potential to be socially accepted as companions, it would be worthwhile for future research to investigate a broader range of women's emotional reactions beyond jealousy-related discomfort.

Furthermore, future studies on jealousy in the context of human-robot interaction should integrate a wider range of gender and sexuality. This would include not only homosexual women and their reactions to sexualized female-looking robots but also jealousy-related reactions of men towards female- and male-looking sexualized robots. Based on research showing that some heterosexual men are intimidated by the thought of their female partner using a vibrator, it is realistic to assume that robots also have the potential to evoke reactions of jealousy in heterosexual males [30].

It should also be mentioned that the present study was conducted in Germany, which as a Central European county was found to have a more open-minded attitude towards sexuality (and related concepts like sexual equality) compared to other countries (e.g., the United States) [53, 54]. A study found that women in the United States and in Germany showed similar responses when asked whether emotional or sexual infidelity would distress them more, which indicates that these different countries do have similar responses towards threats to long-term relationships [54]. However, it is conceivable that especially the combination of attitudes towards sexuality (or infidelity and jealousy, respectively) and attitudes towards technology (in this case towards robots) may strongly depend on cultural influences. Moreover, this interaction may be substantially influenced by gender, as studies found that men and women differ in terms of their attitudes towards both technology and sexuality (e.g., [44, 54]). Intercultural studies with an emphasis on gender would therefore contribute to a better understanding of the acceptance of sexualized robots.

6 Conclusion

The present study investigated whether women react with the same level of jealousy towards the idea of their partner having sexual interactions with a (human-like or machine-like) gynoid robot as they would when imagining their partner having sexual interactions with another woman. We assumed that, due to the higher comparability and the greater likelihood of past experiences of other women as sexual competitors, women would feel more discomfort and jealousy in response to another woman. However, it seems not sufficient to state that women in general evoke stronger jealousy-related discomfort than robots. On the contrary, it depends on the subdimension of jealousy. The jealousy-related discomfort was higher for female competitors compared to the robotic ones, for instance regarding the discomfort caused by the idea of sexual intercourse, whereas in other dimensions the robots evoked the same or higher levels of jealousy-related discomfort, such as the discomfort caused by negative self-evaluations in comparison to the competitor or discomfort caused by shared emotional and time resources. Contrary to our expectation, the factors of similarity and comparability did not lead to differences between human-like and machine-like gynoid robots in terms of the different subdimensions of jealousy-related discomfort. It is possible that basic social cues are sufficient to trigger social scripts known from humans-human interactions, which, in turn, result in social comparison and jealousy-related discomfort.

Greater knowledge about the underlying processes of machines could help women to better evaluate the abilities of robots. Moreover, an enhanced willingness to create and shape sexualized technologies of the near future could positively affect females' self-confidence, as such inventions could more strongly respect and represent their needs in terms of both sexuality and societal standing.

Most importantly, our findings should spark further discussion on ethical aspects of human-robot interaction and hopefully result in social and sexual norms to guide responsible robotics developments which will not negatively impact long-term relationships and women's self-evaluation.

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