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Attitudes Toward Robots as Equipment and Coworkers and the Impact of Robot Autonomy Level

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Abstract

Increasingly, people must interact with robot technologies. In this research, we examined attitudes toward robots as equipment and as coworkers and whether these attitudes are affected by the autonomy of the robot among participants living in the United States (Study 1: $N = 1003$; Study 2: $N = 969$). Study 1 revealed that respondents had a more positive attitude toward robots as equipment than as coworkers. Technology use self-efficacy and prior robot use experience were associated with more positive attitudes toward both robot positions. Having a degree in engineering or technology was associated with a positive attitude toward robot coworkers, while neuroticism was associated with a negative attitude. Additionally, technology use self-efficacy was found to have a significant indirect effect on the associations between openness and attitudes toward robots as well as conscientiousness and attitudes toward robots. In Study 2, a three-group online survey experiment showed that teleoperated robots and semi-autonomous robots were preferred as equipment over fully autonomous robots. The robots' autonomy level did not impact attitude toward robot coworkers. Overall, the results suggest that people prefer non-autonomous robots over autonomous robots in the work-life context. The studies provide a comprehensive overview of attitudes toward robots as both equipment and coworkers, and the key predictors of the noted attitudes. The results suggest a readiness for shared autonomy between a human operator and a robot. This should be considered in the design and successful implementation of new robot technologies in workplaces.

Keywords Attitudes · Robots · Autonomy · Robot equipment · Robot coworker

1 Introduction

New-generation robots and artificial intelligence are transforming many fields and performing tasks formerly handled by humans [24]. Consequently, the question of whether automation substitutes or complements human labor is subject to heated and ongoing debate [1, 19]. The discussion on being replaced by robots is closely related to the autonomy of these devices and whether they are considered as human workers or advanced technological tools for human workers to use. Socially capable robots with advanced artificial intelligence will add a new layer to the topic, as they can resemble human workers in more ways than in simply their ability to perform mechanical tasks. Compared to one-function robotic devices, multifunctional robots equipped with advanced artificial intelligence can act more independently without human control and thus have the ability for higher autonomy. In addition to ethical and legal issues, autonomous robots raise questions about humans' perceptions of and reactions to robot autonomy and to its different levels.

In work life, robots can adopt various roles, some of which are to act as an assistive equipment or a coworker. Previous literature on social acceptance of robots has indicated that human attitudes are more positive when a robot is perceived as equipment rather than a coworker [54]. The key difference between these two robot positions relies on their varied degrees of autonomy: robot equipment can be viewed as a one-function tool mostly supplementing human work, whereas robot coworkers may act more autonomously. The distinction is also based on different strategies and attitudes people adopt toward robots when rationalizing and predicting their behavior [17, 18, 55]. For instance, initial evidence for people perceiving robots as somewhat intentional rather than as just a machine has been obtained [44].

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The successful adoption of technology depends on various human factors, such as attitude, subjective norms, voluntariness, performance expectancy, and prior experience [61, 62]. Such factors as voluntariness and performance expectancy refer to how much autonomy humans have in the adoption process and, in the case of advanced social robots, how much can be expected from this type of technology. The level of robot autonomy is also a vital factor in human–robot cooperation, as it directly affects the way that humans and robots interact [59]. Higher levels of robot autonomy may enrich interactions between people and physical devices [59]. However, increasing the autonomy of a robot may also threaten the human's control and sense of autonomy [66], which is a basic need that influences human motivation and wellbeing [15, 16, 53]. Previous studies have indicated that human attitudes toward and perceptions of robots tend to be more positive when robots are perceived as non-autonomous [54, 58, 64, 66].

In this article, we report the results of two empirical studies investigating attitudes toward robots as equipment and as coworkers. First, we analyze respondents' attitudinal preference between robots as equipment and coworkers and the social psychological human factors predicting attitudes toward these robot positions. Second, we examine whether the autonomy level of a robot impacts these attitudes. Hence, factors related to both humans and robots are taken into account and, together, the studies form a comprehensive overview of attitudes toward both robot equipment and coworkers and the key predictors.

2 Robot Autonomy and Human Factors in Attitudes Toward Robots

The level of robot autonomy is central to human–robot interaction, as it crucially affects the way humans and robots interact [59]. Currently, most robot technologies still require precoding and constant supervision from humans; fully autonomous robots are still in the early design stage [e.g., 28,31,46]. Robot autonomy research is a multidisciplinary field, comprising numerous definitions of autonomy. Simply, robot autonomy can refer to the ability to perform tasks independently [29]. One definition of autonomy suggested for human–robot interaction research particularly refers to "the extent to which a system can carry out its own processes and operations without external control" [8, p. 77]. Levels of robot autonomy exist on a continuum and have been conceptualized in various ways.

Robots in work-life can be divided, according to their varied roles and degrees in autonomy, namely as a piece of equipment or as a coworker. Robot equipment is here viewed as a one-function tool primarily supplementing human work, whereas robot coworkers are autonomous and function more independently. Robot autonomy may also be approached from the perspective of the different strategies and attitudes people adopt to interact with robots [55]. Intentional stance toward a system, a concept introduced by Dennett [17, 18], is likely be induced when a person perceives the system as intentional. When a person treats the system as a machine, a design stance is more likely to be adopted. Initial evidence for people adopting an intentional stance toward humanoid robots has been obtained [44].

In the case of robots as equipment and coworkers, it is worth considering whether people are more likely to adopt an intentional stance toward a robot when approaching it as a coworker, and perhaps a design stance for a piece of robot equipment. It is possible that people have more positive attitudes toward robots when the robot better meets all of their expectations. If the robot coworker is approached as intentional, one may expect the robot to be somewhat autonomous, motivated and reactive, for instance. If the robot is approached as a machine, the expectation may be narrower, more realistic, and interested mainly in the extent to which it is functioning as designed. Following these lines, we assume that people hold more positive attitude toward robots as equipment than as coworkers, due to different approaches people induce toward them.

The association between robot autonomy and social acceptance of robots is relatively little studied, despite its high relevance for the human robot interaction field. One study found human attitudes to be more strongly negative and the robot to be considered as more threatening when the robot was perceived as autonomous, relative to a non-autonomous robot [66]. Another study indicated that people were more likely to use a robot if they perceived it as not having the ability to function independently, compared to perceptions of an autonomous agent [58]. Some qualitative indications have also been obtained of people feeling safer and preferring to work with teleoperated robots with a human operator, compared to autonomous robots [64]. People were reported as being relatively open to the idea of having a robot coworker, but also stressing the importance of not treating robots as equal to humans, nor letting robots substitute for humans socially.

Human robot collaboration has been also approached from a perspective related to a combination of the strengths of humans and automation, which is a shared autonomy [e.g., 34,49]. Instead of focusing on single-system perspectives, in shared autonomy, human input is integrated with robot autonomy, enabling humans and robots to complete tasks collaboratively [47, 57]. One key issue is that the system may not know what the user is trying to achieve [34]. To collaborate meaningfully with robots, studies have shown people valuing transparency in robots to better understand what the system is doing and why [3, 65]. Balancing robot autonomy seems crucial for meaningful human–robot interaction. However, personal and social human factors should also be considered.

Self-efficacy is one of the guiding factors in human activity and is central to understanding human behavior. Self-efficacy refers to one's beliefs about their capabilities to perform in certain situations [4–6]. Perceived self-efficacy has been widely studied in the contexts of various information technologies [2, 13, 22]. Previously, technology-specific self-efficacy was found to be positively associated with acceptance of new technologies, including robots [32, 40, 50]. However, to date, no study has been conducted on how the self-efficacy experiences are affected by different levels of robot autonomy, thus, whether the robot is a piece of equipment or a coworker.

Personality is also central to understanding human behavior. The Big Five personality traits, also known as OCEAN or the five-factor model, consist of openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism, comprising a widely used taxonomy for measuring personality [20, 35, 42]. According to a recent literature review of personality in human–robot interaction studies by Robert [52], the extrovert has repeatedly been found to react positively to human–robot interaction. However, results regarding other human personality traits and their relationship to perception of robots have been less consistent.

The link between personality traits and self-efficacy is also worth noting. Of the listed five personality traits, the positive association between conscientiousness and self-efficacy has received constant research support [e.g., 12,45,67]. Moreover, self-efficacy has been shown to be positively associated with openness to experience [e.g., 11,60] and extraversion [67]. A negative association, in turn, has been shown between self-efficacy and neuroticism [27].

A literature review has established that socio-demographic factors are associated with attitudes toward robots [23]. In particular, age, sex, and education have been found to be determining factors of attitudes toward robots [25, 33]. However, it is noteworthy that the impact of demographic factors is generally fairly complex; there are also significant variations within social groups. In this respect, studies have highlighted that differences based on socio-demographics may be explained by prior experiences or technical knowledge, which have been found to predict positive attitudes toward robots [7, 23, 51].

3 Research Overview

In this paper, we report results of two online survey studies conducted among respondents living in the United States. In Study 1, we compared respondents' attitudinal preference between robots as equipment, relative to robots as coworkers, and considered the social psychological human factors predicting attitudes toward these two robot positions. In Study 2, we examined whether the level of robot autonomy affects the attitude toward robot equipment or the attitude toward robot coworkers. In Study 1, our hypotheses were as follow:

- S1_H1 Attitude is more positive toward robot equipment than toward robot coworkers.
- S1_H2.1 Extraversion is positively associated with attitudes toward robots.
- S1_H2.2 Technology self-efficacy is positively associated with attitudes toward robots.
- S1_H2.3 Prior robot experience is positively associated with attitudes toward robots.

In Study 2, we ran a three-group online survey experiment, in which participants were split into three experimental groups—fully teleoperated robots, semi-autonomous robots, and fully autonomous robots—after which respondents rated their attitudes toward robots. Pre-registered Study 2 hypotheses (https://osf.io/b98m6) were:

- S2_H1 Respondents express more positive attitude toward fully teleoperated robots than toward fully autonomous robots.
- S2_H2 Respondents express more positive attitude toward fully teleoperated robots than toward semi-autonomous robots.
- S3_H3 Respondents express more positive attitude toward semi-autonomous robots than toward fully autonomous robots.

4 Study 1

4.1 Materials and Methods

Participants. The online survey sample was collected in January 2019 ($N = 1003$, 48.89% male, $M_{age} = 37.36$ years, $SD_{age} = 11.80$ years). Respondents reported living in 47 different states and territories, with the highest response rates coming from California (8.91%), Texas (7.59%), and Florida (6.49%). Almost one-third of the respondents (30.01%) had prior robot use experience, but most of the respondents had not (66.80%) or were not sure (3.19%) if they had used or interacted with a robot before.

Procedure. Amazon Mechanical Turk's (MTurk) pool of respondents was utilized to recruit study participants [9, 14, 48]. The research group administrated the survey on the Tampere University server using Limesurvey software. We followed the procedure, suggested by Kennedy et al. [36], to ensure the quality of study participants. Before the experiment, respondents were asked about socio-demographic information, personality, technology use self-efficacy, and prior experience with robots. The Academic Ethics Committee of Tampere region stated in December 2018 that the study does not include any ethical concerns. All analyses were performed with Stata 16 software.

Measures. A descriptive overview of study variables is presented in Table 1. Attitude toward robot equipment was operationalized by asking "How comfortable would you be about using a robot as equipment at work?", and attitude toward robot coworkers, with the question, "How comfortable would you be about having a robot as your co-worker?"; participants rated their attitude on a scale, ranging from 1 (*Totally uncomfortable*) to 7 (*Totally comfortable*). The variables were positively correlated ($r = 0.56$, $p < 0.001$), but as the connection remained moderate, we conducted separate analyses for both outcome variables.

We measured respondents' gender as binary (0 = male, 1 = female) and age as continuous (in years). The educational attainment was scored on a scale from 1 to 5. A dummy variable was created for the analysis (0 = else, 1 = highly educated). The "highly educated" group was comprised of respondents holding a college degree, a master's degree, a professional degree, or higher, whereas the category "else" included some college, high school diploma, and less than a high school diploma. A degree in engineering or technology was measured as binary (0 = no, 1 = yes), by asking "Do you have a degree from the field of engineering or technology?" Personality traits were measured with a 15-item Big Five Inventory, on a scale ranging from 1 (*Strongly disagree*) to 7 (*Strongly agree*) [41]. Three-item sum variables showed acceptable levels of inter-item consistency: neuroticism ($\alpha = 0.88$), extroversion ($\alpha = 0.86$), openness to experience ($\alpha = 0.79$), agreeableness ($\alpha = 0.67$), and conscientiousness ($\alpha = 0.71$). The technology use self-efficacy measure was formed as, "I think I can learn to use new technology easily," which respondents rated on a scale, ranging from 1 (*Strongly disagree)* to 7 (*Strongly agree*). Participants indicated their prior robot use experience by choosing from "Yes," "No," or "Don't know," out of which a dummy variable was created (0 = No/Don't know, 1 = Yes).

Statistical analysis. On top of descriptive statistics, a t-test, linear regression equations, and additional mediation analyses were conducted. For mediation analysis, we ran a KHB package [37] that has been used for Sobel mediation tests in previous studies [e.g., 26,38,56]. We utilized 2000-replication bootstrap, which is considered as one of the most reliable methods in mediation analysis [30, 43]. In regression analysis, variables were introduced to the models in a specific order to enable meaningful interpretation of changes in coefficients. Model 1 included age, female gender, education, degree in engineering or technology, and prior robot experience; Model 2 added Big Five personality traits, and Model 3 added technology use self-efficacy.

We reported unstandardized (B) and standardized (β) regression coefficients, standard errors (*SE B*), model goodness-of-fit measures (R^2), and model test (F) and p values. Multicollinearity was not detected in the regression models, but a significant Breusch-Pagan test indicated problems in heteroscedasticity of residuals in the model assessing attitude toward robot equipment. To resolve the problems in heteroscedasticity, we report on the robot equipment regression model with robust Huber-White standard errors in Table 2. Outliers were detected by Cook's distance measure, in which values greater than 4/N indicate possible problems. To control the potential bias due to outliers suggested by [63], we did an additional analysis, running robust regressions with rreg command in Stata for both robot equipment and coworker models. As the results did not change, in terms of significance of association, we report on the two robust regression models in the appendices A and B.

4.2 Results

According to the comparison of means, respondents' attitude toward robot equipment ($M = 5.23$, $SD = 1.54$) was significantly more positive than the attitude toward robots as coworkers ($M = 4.32$, $SD = 1.85$; $t[1002] = 17.9174$, $p < 0.001$).

Results of the linear regression model for robot equipment are presented in Table 2. In Model 1, prior robot experience ($\beta = 0.15$, $p < 0.001$) was found as a positive predictor of attitude toward robot equipment. In Model 2, in addition to prior robot experience, openness to experiences ($\beta = 0.11$, $p = 0.002$), and conscientiousness ($\beta = 0.11$, $p = 0.011$) were positively associated, and neuroticism had a moderate negative association with the attitude ($\beta = -0.07$, $p = 0.049$). In Model 3, technology use self-efficacy ($\beta = 0.38$, $p < 0.001$), and prior robot experience ($\beta = 0.11$, $p < 0.001$) remained the only significant predictors. The final regression model including all the variables was statistically significant and explained 20% of the variance ($R^2 = 0.20$, $F = 22.79$, $p < 0.001$).

As adding technology use self-efficacy to the model removed the significant association between attitude toward robot equipment and openness, conscientiousness, and neuroticism, additional mediation analyses were conducted. Indeed, technology use self-efficacy was found to have a statistically significant indirect effect on the association between openness to experiences and attitude toward robot equipment ($b = 0.04$, $SE = 0.01$, $z = 5.24$, $p < 0.001$, 95% CI [0.02, 0.05]), and between conscientiousness and attitude toward robot equipment ($b = 0.04$, $SE = 0.01$, $z = 5.00$, $p < 0.001$, 95% CI [0.02, 0.05]). The result was not significant for neuroticism ($p = 0.564$). The models were controlled for all demographics and the remaining personality variables.

Table 1 Summary of descriptive statistics of the Study 1 variables (N = 1003)

Categorical measures	n		%		
Gender					
Female	505		51.11		
Male	483		48.89		
A degree in engineering or technology					
Yes	203		20.24		
No	800		79.76		
Education					
Higher education	608		60.62		
Else	395		39.38		
Prior robot experience					
Yes	301		30.01		
No/Don't know	702		69.99		
Continuous measures	*M*	SD	Range	*n* of items	*α*
Attitude toward robot equipment	5.23	1.54	1–7	1	
Attitude toward robot coworkers	4.32	1.85	1–7	1	
Age	37.36	11.80	19–78	1	
Technology use self-efficacy	5.64	1.20	1–7	1	
Personality traits					
Neuroticism [BF]	11.04	5.23	3–21	3	0.88
Extraversion [BF]	11.25	4.79	3–21	3	0.86
Openness [BF]	15.62	3.81	3–21	3	0.79
Agreeableness [BF]	15.53	3.59	3–21	3	0.67
Conscientiousness [BF]	16.56	3.39	3–21	3	0.71

Table 3 shows the results of the linear regression model for attitude toward robot coworkers. In Model 1, prior robot experience ($\beta = 0.12$, $p < 0.001$) and a degree in engineering or technology ($\beta = 0.10$, $p = 0.005$) were positively, and female gender ($\beta = -0.08$, $p = 0.012$) was negatively associated with attitude toward robot coworkers. In Model 2, a degree in engineering or technology ($\beta = 0.11$, $p = 0.001$), prior robot experience ($\beta = 0.11$, $p = 0.001$), and openness to experiences ($\beta = 0.10$, $p = 0.002$) were positive predictors, and neuroticism was negatively associated ($\beta = -0.09$, $p = 0.020$). In Model 3, technology use self-efficacy ($\beta = 0.30$, $p < 0.001$), a degree in engineering or technology ($\beta = 0.09$, $p = 0.005$), and prior robot experience ($\beta = 0.08$, $p = 0.008$) were positively, whereas neuroticism was negatively associated ($\beta = -0.08$, $p = 0.024$) with the attitude. The final regression model was significant, and together, the variables explained 14% of the variance ($R^2 = 0.14$, $F = 14.99$, $p < 0.001$).

As in the first model, technology use self-efficacy was found to have a significant indirect effect on the association between openness to experiences and attitude toward robot coworkers ($b = 0.03$, $SE = 0.01$, $z = 4.85$, $p < 0.001$, 95% CI [0.02, 0.05]), as well as between conscientiousness and attitude toward robot coworkers ($b = 0.03$, $SE = 0.01$, $z = 4.78$, $p < 0.001$, 95% CI [0.02, 0.05]). Again, the models were controlled for all demographics and the remaining personality variables.

4.3 Discussion

Robots can adopt various roles in human working life, some of which involve functioning as a tool or a coworker. In this study, respondents' attitude was found to be more positive toward robot equipment than robot coworkers, which is in line with previous findings on robot autonomy and social acceptance of robots [54, 58, 64, 66]. However, the attitude was relatively positive for both positions given to robots, as the mean values were well above average on a scale of 1–7. As expected, technology use self-efficacy and prior robot use experience positively predicted attitudes toward robot positions. Similar findings have been obtained regarding self-efficacy and acceptance of new technologies, including robots [32, 40, 50], as well as for prior user experiences and technology acceptance [7, 23, 51].

Contrary to expectations, extraversion was not significant predictor of attitude toward either of the robot positions [52]. Neuroticism predicted attitudes negatively, but the result was true only for the attitude toward robot coworkers, not for

Table 2 Regression model for attitude toward robot equipment Study 1 (N = 985)

Measure	Model 1			Model 2			Model 3		
	B	Robust *SE B*	*β*	*B*	Robust *SE B*	*β*	*B*	Robust *SE B*	*β*
Attitude toward robot equipment									
Age	0.00	0.00	0.01	−0.01	0.00	−0.04	−0.00	0.00	0.00
Female gender	−0.17	0.10	−0.05	−0.11	0.10	−0.04	−0.04	0.09	−0.01
Education	−0.07	0.11	−0.02	−0.10	0.10	−0.03	−0.08	0.10	−0.03
Degree in engineering	0.11	0.12	0.03	0.22	0.11	0.06	0.10	0.10	0.03
Prior experience	0.52	0.10	0.15***	0.50	0.10	0.15***	0.38	0.09	0.11***
Neuroticism				−0.02	0.01	−0.07*	−0.02	0.01	−0.07
Extraversion				−0.01	0.01	−0.04	−0.01	0.01	−0.04
Openness				0.05	0.01	0.11**	0.01	0.01	0.02
Agreeableness				0.02	0.02	0.05	0.01	0.01	0.03
Conscientiousness				0.05	0.02	0.11*	0.01	0.02	0.03
Technology use self-efficacy							0.49	0.05	0.38***
Model R^2		0.03			0.08			0.20	
Model *F*		7.13			9.03			22.79	
Model *p*		***			***			***	

Dependent variable: attitude toward robot equipment

$*p < 0.05$. $**p < 0.01$. $***p < 0.001$

Table 3 Regression model for attitude toward robot coworkers Study 1 (N = 985)

Measure	Model 1			Model 2			Model 3		
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Attitude toward robot coworker									
Age	0.01	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.03
Female gender	−0.30	0.12	−0.08*	−0.23	0.12	−0.06	−0.15	0.12	−0.04
Education	−0.22	0.12	−0.06	−0.24	0.12	−0.06	−0.22	0.12	−0.06
Degree in engineering	0.44	0.16	0.10**	0.53	0.16	0.11**	0.42	0.15	0.09**
Prior robot experience	0.47	0.13	0.12***	0.44	0.13	0.11**	0.33	0.13	0.08**
Neuroticism				−0.03	0.01	−0.09*	−0.03	0.01	−0.08*
Extraversion				−0.02	0.01	−0.05	−0.02	0.01	−0.05
Openness				0.05	0.02	0.10**	0.02	0.02	0.04
Agreeableness				0.03	0.02	0.05	0.02	0.02	0.04
Conscientiousness				0.02	0.02	−0.04	−0.01	−0.02	−0.03
Technology use self-efficacy							0.46	0.05	0.30***
Model R^2		0.04			0.07			0.14	
Model *F*		8.09			7.31			14.99	
Model *p*		***			***			***	

Dependent variable: attitude toward robot coworker

$*p < 0.05$. $**p < 0.01$. $***p < 0.001$

robot equipment. Another factor only explaining attitude towards robot coworkers was the degree in engineering or technology. Previously, similar results were observed, to the extent that technological expertise in general has been found to predict positive attitudes toward robots [7, 23, 51].

An additional mediation analysis revealed that, in the case of both robot positions, technology use self-efficacy had a significant indirect effect on the associations between openness and the attitudes, as well as conscientiousness and the attitudes toward robots. Previous studies have provided evidence of the positive association between self-efficacy, openness to experiences [11, 60], and conscientiousness [12, 45, 67].

5 Study 2

5.1 Materials and Methods

The aim of Study 2 was to further analyze whether the level of autonomy of the robot effects attitude toward robot equipment and attitude toward robot coworkers.

Participants. A new online survey sample was collected among U.S participants in April 2019 ($N=969$, 48.85% male, $M_{age}=37.15$ years, $SD_{age}=11.35$ years). Study 2 included only unique participants who had not participated in Study 1. Participants lived in 49 states and territories, with the highest response rates coming from California (8.36%), Florida (7.84%), and New York (7.84%). One-third of the respondents (33.23%) had prior robot use experience, but most were still new to robots as 60.78% had not used robots prior to the study and 5.99% were unsure.

Procedure. Again, the participants were recruited via MTurk, and the researchers administrated the survey on the Tampere University server using Limesurvey software. Respondents were randomly assigned to three experimental groups, each respondent participating in no more than one experimental group. Group A was given a written description of fully teleoperated robots, Group B was provided a description of semi-autonomous robots, and Group C read a description of fully autonomous robots. The full instructions for respondents in Study 2 experiment are provided in the "Appendix C". We chose to use minimal manipulation based only on a written description, due to its fit with our study objectives of assessing attitude toward notions of *automated robots* or *teleoperated robots*, and also in order to minimize other potentially influencing cues such as robot appearance [21]. Based on one of the autonomy levels assigned to them, participants evaluated their attitude toward robot equipment and toward robot coworkers. Randomization of respondents into experimental groups was also examined and found successful, as no statistically significant differences were obtained in terms of sociodemographic information.

Measures. Descriptive statistics on the three experimental groups, according to background variables used in Study 1 and outcome variables, are presented in Table 4. Study 2 used the same questions about attitude toward robot equipment and attitude toward robot coworkers as outcome variables as utilized in Study 1. The normality of both measures was examined. The robot equipment variable was found to be highly negatively skewed (skewness = −0.83), and leptokurtic (kurtosis = 3.41, when 3 equals the normal distribution), whereas the robot coworker variable was moderately negatively skewed (skewness = −0.34), and relatively symmetric in distribution (kurtosis = 2.22, when 3 equals the normal distribution). However, negative skewness of dependent variables is common in attitude measures [39]. Shapiro–Wilk tests showed that neither variable was normally distributed ($p < 0.001$). Considering the relatively large sample size, we decided to continue with the analysis.

Statistical analysis. Analyses were run with Stata 16 software. After collecting descriptive statistics, we used a parametric one-way ANOVA to test differences between means for three experimental groups. Concerning the negative skewness of both dependent variables, we conducted Levene's test for equality of variances using the median [10]. Variances were equal for both measures—using a robot as equipment at work ($F = 1.93$, $p = 0.146$) and having a robot as a coworker ($F = 1.18$, $p = 0.307$). We used a Kruskal–Wallis H-test as a robustness check to justify the results of the one-way ANOVA. Moreover, we conducted an additional ANOVA with the significant predictors found for each robot type in Study 1 as covariates to assess their potential effects on the results. As the results did not change in either case, only one-way ANOVA results are reported. Finally, we used the Tukey multiple comparison post hoc test to compare the means of control groups.

5.2 Results

The one-way ANOVA results for attitudes among the three groups in the experiment are presented in Tables 5 and 6. Based on the results, there is a statistically significant difference between groups in attitude toward robot equipment (F (2) = 5.62, $p = 0.004$), but not in robot coworkers (F (2) = 1.42, $p = 0.242$). For attitude toward robot equipment, experimental Group A, assigned to a fully teleoperated robot ($M = 5.35$, $SD = 1.37$), had the highest mean score, followed by the semi-autonomous robot group ($M = 5.29$, $SD = 1.35$), and then fully autonomous robot group ($M = 4.99$, $SD = 1.57$). Differences between the groups are illustrated in Fig. 1.

Tukey multiple comparison test results indicated two statistically significant differences: the fully autonomous robot ($M = 4.99$) was preferred less than the fully teleoperated robot ($M = 5.35$, $p = 0.006$) and the semi-autonomous robot ($M = 5.29$, $p = 0.022$). Finally, no significant differences between groups were found concerning fully teleoperated and semi-autonomous robots ($p = 0.845$).

5.3 Discussion

In Study 2, the results revealed statistically significant differences between experimental groups for the attitude toward robot equipment, but not for the attitude toward robot coworkers. As a piece of equipment, fully teleoperated and semi-autonomous robots were preferred over fully autonomous

Table 4 Descriptive overview of data and experimental groups in Study 2 (N = 969)

Variables	Group A: fully teleoperated robot			Group B: semi-autonomous robot			Group C: fully autonomous robot		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Dependent variables									
Attitude toward robot equipment	302	5.35	1.37	347	5.29	1.35	320	4.99	1.57
Attitude toward robot coworkers	302	4.49	1.75	347	4.50	1.75	320	4.29	1.82
Demographics									
Age	302	37.68	11.41	347	37.63	11.41	320	36.13	11.20
Female gender	298	0.50	0.50	342	0.51	0.50	314	0.52	0.50
Education	302	0.64	0.48	347	0.69	0.46	320	0.63	0.48
Degree in engineering or technology	302	0.27	0.45	347	0.27	0.45	320	0.26	0.44
Individual variables									
Prior robot experience	302	0.33	0.47	347	0.35	0.48	320	0.31	0.46
Technology use self-efficacy	302	5.61	1.23	347	5.47	1.30	320	5.61	1.20
Personality traits									
Neuroticism	302	10.92	5.08	347	11.12	4.91	320	10.93	5.13
Extraversion	302	11.30	4.89	347	11.34	4.40	320	11.16	4.94
Openness	302	15.49	3.87	347	15.32	3.74	320	15.13	3.80
Agreeableness	302	15.66	3.49	347	15.35	3.49	320	14.84	3.72
Conscientiousness	302	16.47	3.37	347	15.97	3.25	320	16.10	3.32

solutions. However, the difference between fully teleoperated and semi-autonomous robots was not significant. These results are supported by previous literature, to the extent that people have been shown to perceive less autonomous robots more positively than fully autonomous ones [54, 58, 64, 66]. Overall, the results provide interesting indications that people would rather use a piece of robot equipment that requires their own participation in the usage than allow the tool to function entirely autonomously.

Table 5 Analysis of variance of attitude toward robot equipment by experimental groups in Study 2 (N = 969)

	Sum of squares	*df*	Mean square	*F*	*p*
Between groups	23.09	2	11.54	5.62	0.004
Within groups	1984.22	966	2.05		
Total	2007.31	968	2.07		

Table 6 Analysis of variance of attitude toward robot coworkers by experimental groups in Study 2 (N = 969)

	Sum of squares	*df*	Mean square	*F*	*p*
Between groups	8.93	2	4.47	1.42	0.242
Within groups	3037.74	966	3.14		
Total	3046.67	968	3.15		

6 Concluding Discussion

This article reports findings of two survey studies conducted among respondents living in the United States. Study 1 compared respondents' attitudinal preference between robots as equipment and coworkers, and determined the social psychological human factors predicting attitudes toward these two robot positions. Study 2 focused on the features of the robots, namely the effect of level of robot autonomy on the attitudes toward robot equipment and coworkers.

Respondents were concluded to have more positive attitude toward robot equipment, compared to robot coworkers, which confirms the first hypothesis of Study 1. The result from Study 1 sample suggests that people prefer a robot as a piece of equipment rather than as an autonomously functioning worker in the work life context. The results are linked to the ongoing debate over whether robots are taking over human jobs [1, 19]. That is, robot coworkers may evoke connotations of replacing human labor, whereas equipment is more likely to support or complement human work. It is also worth considering whether humans are yet ready to perceive robots as peers in working life, as "coworker" may suggest.

Participants' more positive attitude toward the robot equipment can also originate from the stance that people adopt when approaching the robot. It might be that people perceive the robot equipment primarily as a machine, and thereby adopt a design stance toward it and an intentional stance when approaching the robot as coworker. This leads the expectations for the robot equipment to bear mainly on its functioning as designed; these are relative realistic expectations for a robot to meet (or not). Therefore, it is possible

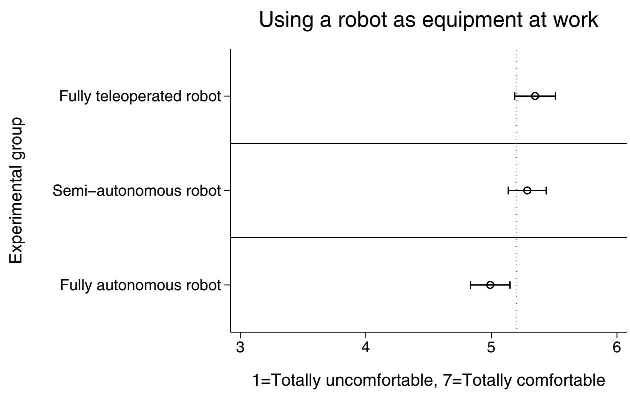

Fig. 1 Attitude toward robot equipment means on a scale of 1–7 by groups in Study 2 (N = 969)

that people feel more comfortable about robot equipment than they feel about robot coworkers, as the former better fits their expectations. Robot equipment may feel safer, as it is not motivated nor does it function in any way independently outside of its assigned core function; as such, it is unlikely to do anything unexpected to humans.

For both robot positions, perceived technology use self-efficacy and prior robot use experience were significant positive predictors for attitudes toward robots, thus confirming our second and third hypotheses for Study 1. The results complement the literature on perceived technology related self-efficacy by showing its positive association with attitudes toward both robot positions, namely as pieces of equipment and coworkers. The results also suggest that one's confidence in own abilities to use new technology in general extend to robot technologies as well. That self-efficacy experiences can expand from a certain task or domain to another similar one has also been noted in its own theory [5, 6]. As expected, previous user experiences predicted more positive attitudes toward robots. However, in the future, we look to delve more deeply into the quality of past experience to form even more comprehensive conclusions.

Contrary to expectations, extroversion was not positively associated with the attitudes toward robots. Overall, personality traits did not show a significant relationship to the attitudes in the final models. An exception was neuroticism, which had a moderate negative association with attitude toward robot coworkers indicating that people experiencing neuroticism may hold more negative attitude toward autonomous agents. One interpretation is that people are less likely to experience a sense of control over an autonomous device [66, 68], which may cause discomfort, especially for those experiencing neuroticism.

Having a degree in technology or engineering was another significant factor, which positively predicted attitude toward robot coworkers only. It is worth considering whether a background in the field of technology helps to build a more realistic view of technology's capabilities, which in turn decreases uncertainty regarding robots. In the future, research can benefit from a more detailed sectorial comparison regarding perceptions of robots in work life. All the significant associations obtained in Study 1 regression models were also found in the robust regressions, which justifies the results.

In Study 2, the main focus of analysis was to investigate whether the level of robot autonomy impacts the attitude toward both robot equipment and robot coworkers. According to results, there were statistically significant differences between experimental groups for the attitude toward robot equipment, but not for the attitude toward robot coworkers, while taking the human factors into account. The results were also true when considering the significant predictors found in Study 1 final models for both robot positions, which further strengthens the findings. The results suggest that the degree of robot autonomy is an important determinant for attitude toward robot equipment but has a smaller role in attitude toward robots as coworkers. Several explanations can be considered. It might be easier for respondents to imagine different levels of autonomy for a robot equipment than for a robot coworker, as the former may be more familiar to respondents. Also, the perception of a robot as a coworker may already contain an assumption of some kind of autonomy making the evaluation of its different levels no longer as meaningful for respondents.

As a piece of equipment, fully teleoperated and semi-autonomous robots were preferred over fully autonomous robots, thus confirming our first and third hypotheses for Study 2. However, the difference between attitude toward fully teleoperated and attitude toward semi-autonomous robots was not significant, emphasizing the reluctance related to fully autonomous robots, also in the form of an equipment. In relation to the concept of robot autonomy in general, the preference for less autonomous robots found in our study reflects that the level of autonomy impacts the acceptance and, thus, might have unfavorable consequences for readiness to interact with highly autonomous robots. Robot autonomy as robots' capability to perform tasks independently without external control [8, 29], is, based on our results, perceived less favorable when no human input is needed at all.

Participants demonstrated willingness to participate in robot equipment teleoperation instead of letting the robot equipment function independently. Alternative explanations can be made; what the robot can do with its autonomous functions may be a matter of uncertainty. Moreover, some people may be suspicious of robots and artificial intelligence, thinking that they might overtake personal space, and thereby threaten the human's sense of autonomy and control [15, 16, 53, 66]. Another aspect can be that people are willing to learn to better understand new technologies by using them themselves in a concrete way when the opportunity arises. The findings have implications for interest in combining the strengths of humans and automation, that is the shared autonomy [34, 49]. In the case of fully teleoperated and semi-autonomous robot equipment, human input is integrated with robot capabilities, which may in fact be the currently preferred form of human–robot collaboration.

It is critical to consider whether imagining a fully autonomous piece of equipment or a fully human-driven robot coworker have presented challenges to those respondents with little or no experience with robots. For this reason, we controlled for the effect of prior robot experience in our analyses. In our study, the respondents expressed their attitude, knowing the level of robot autonomy based on brief written descriptions. However, we chose not to picture robots more precisely, as it is known that the appearance of a robot affects the estimation of its capabilities [21].

The limitations of our research were methodological, relating to the self-reported information and non-representative nationwide data sampling. However, the sample was geographically widespread, and participants came from various sociodemographic backgrounds. Single question items were used for addressing attitude toward robot equipment and toward robot coworkers in both studies as well as for the effectiveness of the autonomy manipulation in the second study, which must also be taken into account as possible limitations when interpreting the results. The study followed a cross-sectional design; therefore, continuing the examination to enable a longitudinal analysis is important to further justify our findings. In addition, research examining human reactions to robots with different levels of autonomy in real-life settings may necessarily supplement the literature.

Our results showed that participants hold more positive attitude toward robots when they perceive them as equipment, compared to robot coworkers. In terms of robots as pieces of equipment, participants preferred less autonomous robots. Results suggest that people are willing to participate in robot teleoperation rather than letting the robot equipment function autonomously. Furthermore, the results showed that participant's attitude toward robots as both equipment and coworkers related to their previous user experiences and perceived self-efficacy in using new technologies. A degree in technology and neuroticism emerged as important factors predicting attitude toward robot coworkers.

Our studies provide a comprehensive overview of attitudes toward robots as both equipment and coworkers, and the key predictors of those attitudes. Overall, the results indicated that people prefer non-autonomous robots to autonomous robots in the work-life context. The results can be utilized for the design and successful implementation of new robot technologies in modern work life.

Appendix A

Table A Robust regression analysis for attitude toward robot equipment Study 1 (N = 985)

Measure	*B*	*SE B*	*p*	95%	CI
Age	0.00	0.00	0.943	−0.01	0.01
Female gender	−0.05	0.09	0.536	−0.22	0.12
Education	−0.06	0.09	0.496	−0.23	0.11
Engineering degree	−0.02	0.11	0.857	−0.24	0.20
Prior robot use experience	0.27	0.09	0.003	0.10	0.45
Neuroticism	0.00	0.01	0.618	−0.02	0.01
Extraversion	0.00	0.01	0.745	−0.02	0.01
Openness	0.02	0.01	0.106	0.00	0.04
Agreeableness	0.01	0.01	0.325	−0.01	0.04
Conscientiousness	0.01	0.01	0.317	−0.01	0.04
Technology use self-efficacy	0.59	0.04	< 0.001	0.52	0.66

Dependent variable: attitude toward robot equipment.

Appendix B

Table B Robust regression analysis for attitude toward robot coworker Study 1 (N = 985)

Measure	*B*	*SE B*	*p*	95%	CI
Age	0.00	0.01	0.357	−0.01	0.01
Female gender	−0.15	0.13	0.220	−0.40	0.09
Education	−0.23	0.12	0.060	−0.48	0.01
Engineering degree	0.43	0.16	0.007	0.12	0.74
Prior robot use experience	0.31	0.13	0.019	0.05	0.57
Neuroticism	−0.03	0.01	0.037	−0.05	0.00
Extraversion	−0.02	0.01	0.225	−0.04	0.01
Openness	0.02	0.02	0.153	−0.01	0.06
Agreeableness	0.01	0.02	0.463	−0.02	0.05
Conscientiousness	−0.01	0.02	0.539	−0.05	0.03
Technology use self-efficacy	0.52	0.05	< 0.001	0.42	0.63

Dependent variable: attitude toward robot coworker.

Appendix C

Instructions for respondents in Study 2 experiment.

Respondents were instructed in the experiment as follows:

GROUP A When thinking about *fully teleoperated robots* (robots fully operated by a human), how comfortable would you be about

GROUP B When thinking about *semi-autonomous robots* (robots which partly share control with a human), how comfortable would you be about

GROUP C When thinking about *fully autonomous robots* (robots acting independently without human intervention), how comfortable would you be about

… using a robot as equipment at work?

… having a robot as your co-worker?

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