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Subgroup formation in human–robot teams: A multi-study mixed-method approach with implications for theory and practice

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Abstract

Human–robot teams represent a challenging work application of artificial intelligence (AI). Building strong emotional bonds with robots is one solution to promoting teamwork in such teams, but does this come at a cost in the form of subgroups? Subgroups—smaller divisions within teams—in all human teams can undermine teamwork. Despite the importance of this question, it has received little attention. We employed a mixed-methods approach by conducting a lab experiment and a qualitative online survey. We (a) examined the formation and impact of subgroups in human–robot teams and (b) obtained insights from workers currently adapting to robots in the workplace on mitigating impacts of subgroups. The experimental study (Study 1) with 44 human–robot teams found that robot identification (RID) and team identification (TID) are associated with increases and decreases in the likelihood of a subgroup formation, respectively. RID and TID moderated the impacts of subgroups on teamwork quality and subsequent performance in human–robot teams. Study 2 was a qualitative study with 112 managers and employees who worked collaboratively with robots. We derived practical insights from this study that help situate and translate what was learned in Study 1 into actual work practices.

1 | INTRODUCTION

Human–robot teams are changing the way we organize work, but they also present the challenge of integrating humans and robots into a coherent and seamless work group. Human–robot teams represent a widespread application of artificial intelligence (AI) to work settings (Azevedo-Sa et al., 2021; Østerlund et al., 2021). Robots are artificially intelligent machines with a physical embodiment being deployed to work with humans (You & Robert, 2018). The physical embodiment of robots makes them distinct from other AI technologies. Robots are used to help workers in such diverse settings as hospitals and public libraries to pack boxes and clean hallways (Lin et al., 2014; Pee et al., 2019).

Building strong emotional bonds between humans and robots is one approach to integrating humans and robots, but does it come at a cost? Generally, emotional bonds between humans and technology have been viewed as beneficial because they promote adoption and lead to higher engagement, enjoyment, and performance (K.-K. Kim et al., 2010; Mugge et al., 2009; Robert, 2017; Waheed et al., 2015). Research on human–robot teaming also suggests that individuals develop strong bonds with robots (You & Robert, 2018). Although much attention has been directed at the positive outcomes of these emotional bonds, little effort has been paid to understanding the drawbacks.

The emergence of subgroups might be one cost of promoting strong emotional bonds between humans and robots. Research on subgroups has shown that strong bonds within a subdivision of a team relative to the bonds across the team can lead to subgroups within the team (see Carton & Cummings, 2012, for a review). Subgroups can divide the team and create discord (Bos et al., 2010; O'Leary & Mortensen, 2010). However, is it possible that humans can form bonds strong enough with robots to create subgroups? According to the literature, humans can and do develop emotional bonds with robots much like they do with other humans (You & Robert, 2018). This suggests that the human–robot relationship within a team could act as the basis for a subgroup. If this is true, would the emergence of subgroups be detrimental?

This topic remains relatively unexplored despite the potential importance of subgroups in human–robot teams. Nonetheless, robots are increasingly being designed to elicit strong emotional bonds from human collaborators to help promote acceptance (Willemse & van Erp, 2019). Thus, it is essential to understand when such efforts are likely beneficial or counterproductive. Moreover, if subgroups were found to influence human–robot team outcomes, it would be imperative to understand how organizations could address this in practice. To address this, we report findings from two studies based on a mixed-methods approach (Creswell, 2021; Creswell & Clark, 2017; Fetters, 2019): an experiment (Study 1) and a qualitative online survey with open-ended questions (Study 2). Investigation of this issue speaks directly to recent calls to examine the degree to which AI in work reproduces existing structures and addresses the need to conduct research that can guide the information community in this area (Jarrahi et al., 2021).

This paper makes several contributions to the literature on artificial intelligence (AI) and the future of work in organizations. First, this paper examines the degree to which robots in work teams reproduce existing structures in the form of subgroups, and their implications for workers. The findings call to attention the need to extend theories of subgroup formation to include AI-enabled technologies such as robots. Second, this paper extends theory on subgroups by identifying moderators that enable or constrain the impacts of subgroups on teamwork. Finally, this paper presents several vital insights from workers adapting to robots in the workplace on mitigating the negative impacts of subgroups in human–robot teams. These insights speak directly to adding to our knowledge on the transformation of work driven by the replacement of workers in various settings.

2 | RESEARCH OVERVIEW

To address these issues, we report findings from two studies. Study 1 was an experiment designed to investigate subgroups and their impacts. Study 2, using a qualitative approach, sought to understand how the findings from Study 1 can help translate into *artful integration of AI and work* (Jarrahi et al., 2021). In doing so, Study 2 situates the findings of Study 1 and highlights how organizations are adapting or could be adapting to robots in the workplace through the voices of current workers attempting to make sense of changing workplace norms. The research overview is illustrated in Figure 1.

3 | BACKGROUND

3.1 | Bonding with robots

Research has shown that strong bonds with a technology artifact can have important implications for use (Xiaofei et al., 2021). The basic premise is that the stronger the bond individuals have with technology, the more they prefer and enjoy using it (Read et al., 2011; Vincent, 2006). Typically, the consequences of this bond are viewed positively. For instance, emotional attachment has promoted an individual's willingness to use and continue to use technology such as a mobile phone (Gerber, 2011). Emotional bonds with technology can also enhance the quality of interactions. For instance, individuals who bonded with their avatars had higher levels of social presence in videogames and had a better shopping experience in virtual worlds (K.-K. Kim et al., 2010; Suh et al., 2011). Similarly, emotional bonds with embodied physical action (EPA) robots can increase the performance and viability in human–robot teams (You & Robert, 2018).

The physical embodiment of robots has made emotional bonds crucial to understanding our interactions with robots (Groom & Nass, 2007). Physical embodiment distinguishes robots from other digital objects, such as chatbots, recommendation agents, and avatars (Schifferstein & Zwartkruis-Pelgrim, 2008; Ziemke et al., 2015). The physical embodiment allows for more visceral and tangible experiences, such as touching, and allows humans to exist in the same physical space with robots in real-time (Dourish, 2001). Individuals are often more engaged with

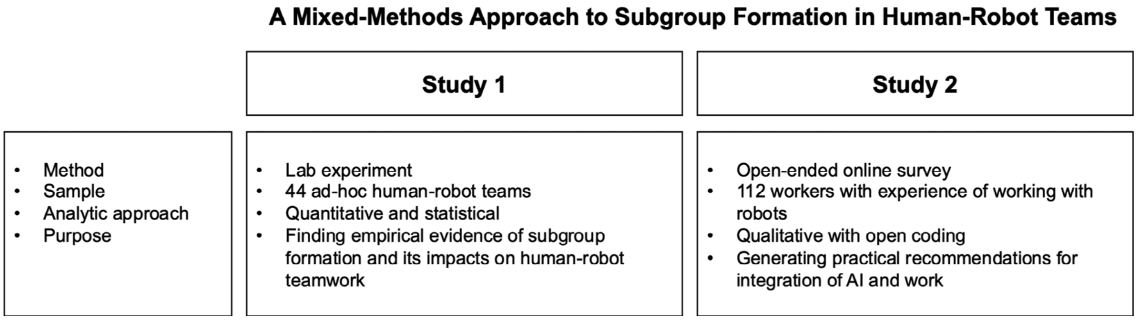


FIGURE 1 Research overview

physical objects and exert more effort to maintain relationships with them (Huang et al., 2013). This explains, in part, why people can build emotional bonds with physically embodied agents like robots more easily than with virtual avatars (Groom & Nass, 2007; Lee et al., 2006).

3.2 | Subgroup formation in teams: Good or bad?

The study of subgroups acknowledges that a team often functions less like a coherent whole and more like several incoherent parts. A subgroup is a subset of two or more members of a team (Carton & Cummings, 2012). Subgroups form when bonds within a subdivision of a team are stronger than bonds across the entire team. The presence of subgroups has been associated with negative implications. Subgroup formation has been found to reduce teamwork by undermining trust and satisfaction while increasing conflict (Mäs et al., 2013; Robert, 2016a; Yilmaz & Peña, 2014). Traditionally, subgroup formation has been studied in collocated teams, but recent studies have found evidence of subgroups in virtual teams (Polzer et al., 2006; Robert, 2016b). Like in collocated teams, subgroups in virtual teams have been associated with lower trust, identification, and transactive memory as well as increases in conflict and coordination problems (O'Leary & Mortensen, 2010; Spell et al., 2011).

Despite the evidence linking subgroup formation to adverse outcomes, several examples link subgroups to positive outcomes. Gibson and Vermeulen (2003) proposed and found evidence that subgroup formation actually increases team learning by providing social support for team members within a subgroup. Their logic was that emotional bonds within a subgroup, if not too strong, are actually beneficial rather than detrimental to teamwork. Theoretically, Carton and Cummings (2012) suggested that subgroups could be equally bad or good depending on contextual factors. Empirically, other studies found evidence to support this assertion by finding that subgroups can increase social integration, open communications, and feelings of fairness (Robert, 2016b; Spell et al., 2011). Nonetheless, overwhelming evidence indicates that subgroups are detrimental (see Thatcher & Patel, 2012).

Despite the importance of subgroups in teams, we know very little regarding whether robots contribute to the formation of subgroups and their effects on team outcomes. However, it is possible that a team of two humans each working with a robot could fracture into two human–robot subgroups based on each human's strong bond with his or her robot. We learned from prior research that people often develop strong emotional bonds with their robots (Björling et al., 2020). The bonds are as strong as or stronger than those developed with other humans and pets (Melson et al., 2009). Therefore, we believe that human–robot bonds can lead to subgroup formation. Thus, we investigated the existence of human–robot subgroups and the implications associated with the outcomes of human–robot teams.

4 | STUDY 1: SUBGROUP FORMATION IN HUMAN–ROBOT TEAMS

In Study 1, we developed and empirically examined a theoretical model (Figure 2). The model draws from social identity theory (Hogg et al., 2004) to describe how identity-based bonds can result in subgroups in human–robot teams and their impact on teamwork quality. Teamwork quality is the degree to which team members feel supported by teammates and enjoy and are satisfied with their team's work (Dayan & Di Benedetto, 2008).

4.1 | Robot identification impacts human–robot subgroups

Robot identification (RID) is associated with increases in subgroup formation in human–robot teams. RID is the extent to which an individual personally bonds with a

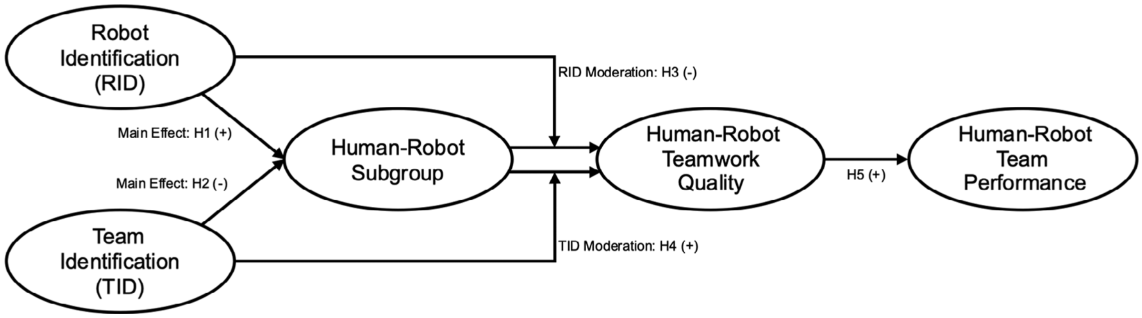


FIGURE 2 Research model

robot (You & Robert, 2018). RID can be viewed through the lens of self-extension (Hewstone et al., 2008). Self-extension occurs when individuals identify with others and view them as an extension of who they are, rather than a separate social being (Belk, 2013). Research suggests that self-extension is irrespective of anthropomorphism of others and not limited to humans but also includes concrete objects and abstract ideas (Hewstone et al., 2008). Therefore, self-extension, as it pertains to material identification, literally means to extend oneself to include a material object when an individual becomes attached to a material object (Mugge et al., 2009). Self-extension has been used to explain brand identification (C. K. Kim et al., 2001), digital goods (Belk, 2013), and avatars (Suh et al., 2011; You & Sundar, 2013).

RID represents a strong attachment to the robot (You & Robert, 2018). RID speaks to the individual-level psychological process based on individuals' relationship with their robots. However, in teams working with multiple robots, members use and control their own robot as part of their work with others (Yanco & Drury, 2004). Thus, the shared experience of identification with a robot can also be viewed as a team-level phenomenon. In such cases, subgroup formation is likely to occur when individuals have a stronger relationship within their subdivision than across the team as a whole (Cronin et al., 2011). In a human–robot team, the relationship between individuals and their robot could engender a subdivision within the team. All things being equal, the likelihood of subgroup forming should increase as an individual's identification with his or her robot increases.

> **H1.** *Robot identification increases subgroup formation.*

4.2 | Team identification impacts human–robot subgroups

Team identification (TID) should be associated with decreases in subgroup formation in human–robot teams. TID is defined as "the extent to which members are psychologically identified with a group" (Scott, 1997, p. 120). TID occurs when individuals believe their identity overlaps with the team's identity (Van Der Vegt & Bunderson, 2005). TID facilitates inter-team relationships by increasing trust and reducing conflict while promoting cohesion and a sense of shared faith (You & Robert, 2018). TID has been described as the glue that binds team members (Rapp & Mathieu, 2019).

Teams with members who are psychologically bonded to the team as a whole are less likely to fracture into subgroups (Ren et al., 2014). Conversely, fractures are likely to occur when individuals have a stronger relationship within their subgroup (i.e., robot partner) than across the team (Dovidio & Gaertner, 2000). Thus, as TID increases, there is a greater chance that a strong team bond would offset any potential subgroup formation with members and their robots. Empirically, several meta-analyses offer substantial evidence to support this assertion (see Carton & Cummings, 2012, for a review).

> **H2.** *Team identification decreases subgroup formation.*

4.3 | Robot identification and team identification impact human–robot subgroups

Scholars have highlighted that contextual factors/moderators might determine when subgroups are likely to be beneficial or detrimental (Carton & Cummings, 2012). On the one hand, subgroups can lead team members to make negative attributions about outgroup members, leading these outgroup members and their actions to be viewed negatively, which facilitates conflict, frustration, anxiety, and discomfort, all of which should degrade teamwork quality (Esterwood et al., 2021; Lipponen et al., 2003). Subgroup formation can also reduce motivation. Research on effort-withholding has shown that negative attributions to one's teammate are associated with members putting less effort toward the team's objectives (Srinivasan et al., 2012). On the other hand, subgroups allow for strong emotional bonds, which can lead to more enjoyment and satisfaction (Gibson & Vermeulen, 2003). Next, we provide a detailed argument for why robots and TID are likely to be significant moderators.

RID should moderate the relationship between subgroup formation and teamwork quality in human–robot teams. As stated, the formation of subgroups in and of itself is not always a bad thing. In fact, subgroups could actually be a good thing. However, subgroups are likely to hurt teamwork quality when RID is high. High levels of RID indicate a strong and potentially problematic subgroup. When this occurs, we are likely to see the negative effects typically associated with subgroups (Gibson & Vermeulen, 2003). Conversely, subgroups should positively impact teamwork quality when RID is low. When RID is low, the subgroup can provide support and an enjoyable team experience without the negative side effects of interfering with the team's collective effort.

> **H3.** *Robot identification moderates the impact of subgroups on teamwork quality by decreasing quality when robot identification is high and increasing quality when robot identification is low.*

We propose that TID determines when subgroup formation can positively or negatively impact teamwork quality. Theories around multiple identifications in organizations assert that identification with a smaller target can positively impact when that identity is nested within a larger superordinate identity. Richter et al. (2006) examined the impact of workgroup identification on inter-workgroup conflict and productivity. They found that when employees identified with their organization, workgroup identification was associated with decreased conflict and inter-workgroup productivity. Van Dick et al. (2008) found that workgroup identification only leads to more job satisfaction and extra-role behavior when employees also identify with their organization.

Richter et al. (2006) and Van Dick et al. (2008) did not examine subgroup formation. However, given these findings, we expect TID to moderate the impact of subgroup formation in human–robot teams. Subgroup formation should increase teamwork quality when TID is high. When this occurs, teams should benefit from the emotional bonding provided by the subgroup and the collective identity. However, when TID is low, subgroup formation represents the divisiveness associated with subgroups. When this occurs, subgroup formation should reduce teamwork quality.

> **H4.** *Team identification moderates the impact of subgroup formation on teamwork quality by increasing quality when team identification is high and decreasing quality when team identification is low.*

4.4 | Teamwork quality and team performance

We posit that teamwork quality increases the performance of human–robot teams. Teamwork quality has been positively associated with team performance (Hoegl & Gemuenden, 2001). Specifically, we propose that teamwork quality can lead humans in human–robot teams to be more motivated and committed to the team. Teamwork quality often indicates good interaction, coordination, and communication among teammates and the effective use of the robots, all of which contribute to better team performance (Hoegl & Gemuenden, 2001; Robert et al., 2018).

> **H5.** *Teamwork quality increases team performance.*

4.5 | Study 1 method

As part of a larger research project, we conducted a 3×1 between-subjects lab experiment with individuals. We recruited participants through a university-wide subject pool that consisted of more than 2,000 individuals, including undergraduate and graduate students, university staff, and alumni. We randomly assigned 88 individuals (mean age = 23.6 years, standard deviation [*SD*] = 4.1 years, 42 females) to 44 teams, each consisting of two humans and two robots. Teams were randomly assigned to one of three conditions: RID (15), TID (14), and controls (15). Each participant was paired with a robot to accomplish a team subtask. Participants were paid $20 and could receive additional compensation based on their team performance.

4.5.1 | Experimental task and robots

The objective of the team task was to move five bottles from Point A to Point C (see Figure 3). There were marks on the experimental setting area indicating Points A, B, and C. Teams were asked to use their robot to move five bottles from Point A to Point C as quickly as possible. One teammate used his or her robot (i.e., Human–Robot Subgroup 1) to deliver bottles from Points A to B. Then, using his or her robot (i.e., Human–Robot Subgroup 2), the other teammate delivered the bottles from Points B to

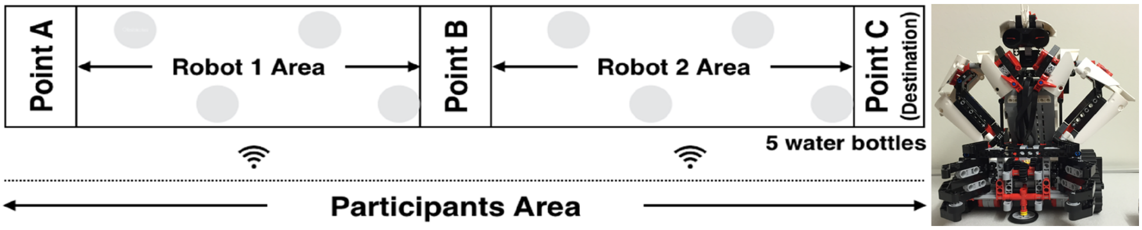


FIGURE 3 Experimental task setting and robot

C. The task was an interdependent and collaborative team task, in that Human–Robot Subgroup 1 was not allowed to deliver bottles beyond Point B, and Human–Robot Subgroup 2 could only pick up water bottles from Point B. There were obstacles along the route, and the participants were allowed to talk and share information to complete the task. The task was completed after five bottles were moved from Point A to Point C. The robots were designed, based on LEGO Mindstorms EV3, to grab small objects. The robots spoke the word "okay" to indicate intelligence when successfully grabbing and releasing objects.

The task and the robots above are used for two reasons. First, most robots are semi-autonomous and are supervised or operated by humans. Second, robots are often employed to perform work that requires some movement of physical objects (Yanco & Drury, 2004). For example, robots are employed for this task type in several settings such as urban search and rescue teams, delivery services, warehouses, and policing (Baker et al., 2018; Carpenter, 2014; González, 2017). Finally, prior research shows that people attribute greater agency to such robots when working collaboratively with them, leading to strong emotional bonds even with non-autonomous robots (Carpenter, 2014; Huang et al., 2013).

4.5.2 | Experimental conditions

Robot identification

This treatment asked teams to finish assembling their robot before performing the task. Team members assembled their robot's head and added it to the body. Each participant was given a robot without a head, parts to complete the robot's head, and written instructions. The two individuals in each team were each asked to assemble their own robot.

Team identification

This treatment asked teams to create a team name and choose a t-shirt as a team uniform. The uniform had the same design and color for both human members and robots. For example, when a team chose a yellow t-shirt, both team members were given two yellow infant t-shirts and asked to put them on their robots. All teams in the TID condition were asked to wear the chosen t-shirts and keep the small t-shirts on the robots during the team task.

Controls

These participants were not given any of the above treatments. The control teams were given two complete robots and were not given t-shirts or asked to pick a team name.

4.5.3 | Procedure

Participants were given a brief study introduction with consent forms. The information explained that they were competing against other teams and could receive additional compensation based on their team performance. Participants were guided to a treatment room where two computers and experimental treatments were placed upon consenting. Participants were asked to fill out a short pretreatment questionnaire, which collected demographics and control variables. Then, participants received both written and video instructions on the task and how to operate the robot. Next, participants were exposed to their treatment or not, depending on the random assignment. Then, participants moved to another room to perform the team task.

Before the team task, all teams had an opportunity to practice. First, teams were given 3 min to operate their robots freely. Second, teams were given two practice runs, where they performed the delivery task twice. After practicing, teams completed the timed task. The duration of the task was measured. Including the training, participants had approximately 30 min of interaction with the robots. Finally, participants were guided back to the treatment room for a post-treatment questionnaire, debriefed, and paid $20. All participants finished the experimental task.

4.5.4 | Measures

Robot identification

We used seven items based on a five-point scale (1 = *strongly disagree* to 5 = *strongly agree*; Schifferstein &

Zwartkruis-Pelgrim, 2008). One example was, "If I were describing myself to my team members, this robot would likely be something I would mention." The scale was reliable (Cronbach's $\alpha = .89$). RID was increased by the RID treatment ($\beta = .40$, $p < .05$), which shows the success of RID manipulation.

Team identification

TID was captured using six items (Bos et al., 2010) based on a five-point scale (1 = *strongly disagree* to 5 = *strongly agree*). An example item was, "I was happy with being identified as a member of this team." The scale was reliable ($\alpha = .94$). TID was increased by the presence of the TID treatment ($\beta = .33$, $p < .05$), which indicates the success of TID manipulation.

Human–robot subgroup formation

We measured the dyadic bond between the human teammates and compared it against their dyadic bond with their robot to measure subgroup formation. Bonding was measured using a five-item cohesion scale from Craig and Kelly (1999) based on a five-point scale (1 = *strongly disagree* to 5 = *strongly agree*). One example was, "I feel close to this team member (robot)." The scale was reliable (Cronbach's $\alpha = .85$). The cohesion between human teammates (HH_B) was subtracted from their cohesion with their robot (HR_B) (i.e., HH_B–HR_B). Negative values were coded as "1" to represent a subgroup formation, while non-negative values were coded as "0" to represent no subgroup formation. The binary measurement of subgroup formation was designed to find empirical evidence of subgroups by measuring the relative cohesion strength between the humans and robots versus between the humans.

Teamwork quality and team performance

Using a three-item index, we measured teamwork quality based on a five-point scale (1 = *strongly disagree* to 5 = *strongly agree*). The index included items such as, "This team met or exceeded my expectations and fulfilled its overall objectives." The teamwork quality scale was reliable ($\alpha = .91$). Performance was measured by completion time, with lower scores indicating better performance. The average time was 262 s (SD = 52.2 s).

Control variables

We measured participants' previous experience with LEGO Mindstorms and general robotic knowledge, respectively.

It should be noted that the level of analysis for this study was the team level. The responses from the experiment were collected at the individual level and aggregated to the team level. All team-level constructs had intraclass correlation (ICC) values higher than the threshold of .11 (Bliese, 2000).

4.6 | Study 1 results

We conducted a logistic regression analysis to predict subgroup formation (Table 1). The full model compared against the control model was significant, indicating that the predictors—RID and TID—help explain subgroup formation ($\chi^2 = 11.47$, $p < .05$ with $df = 4$). Nagelkerke's R^2, which ranges between 0 and 1, was *0.35*. The accuracy of the prediction overall was 80%. The Wald criteria demonstrated that RID (4.85, $p < .05$) made significant contributions to the prediction. Although this was only marginally significant, TID (−0.80, $p = .10$) had a negative relationship with subgroup formation. RID increased the likelihood of a subgroup formation, whereas TID marginally reduced it. Therefore, H1 was supported, while H2 was marginally supported.

Hypotheses 3 and 4 posited moderation effects of robot and TID on relationships between subgroup formation and teamwork quality. We tested Hypotheses 3 and 4 through the generalized linear model (GLM). We employed the GLM based on the results of Levene's test of dependent variables. The Levene's test is conducted to verify the assumption of the equal variances of errors of groups by rejecting the null hypothesis that the variances are equal. Results of the Levene's test revealed that teamwork quality did not have equal variances ($F = 6.73$, $p < .01$) across the conditions. The violation of the assumption required us to use an alternative to the analysis of variance.

Results are shown in Table 2. Results indicate that both RID ($B = -0.42$, $p < .01$) and TID ($B = 0.22$, $p < .05$) moderate the impacts subgroup formation on teamwork quality (*pseudo* $R^2 = .66$). We calculated pseudo R^2 in the models to estimate the improvement from a null model to fitted models by computing the ratio between the null model deviance and the fitted model deviance (Faraway, 2016). Teamwork quality decreased as subgroup formation increased when RID was high (Figure 4). Subgroup formation increased teamwork quality when TID was high (Figure 4). Hypotheses 3 and 4 were supported.

Hypothesis 5 posited that teamwork quality would increase performance and was supported ($B = -33.89$, $p < .01$) (Table 3). Decreases denoted the positive impact of teamwork quality in task time. Hypotheses testing results are shown in Table 4.

5 | STUDY 2: PRACTICAL IMPLICATIONS OF SUBGROUPS IN HUMAN–ROBOT TEAMS

Study 1 provided evidence that human–robot teams can form subgroups and subgroups can alter

TABLE 1 Results of logistic regression for human–robot subgroup formation

	Human–robot subgroup formation (SGF)					
	Model 1			Model 2		
Independent variable	B	SE	Wald	B	SE	Wald
Constant	−1.40***	0.41	11.43	−1.70***	0.51	11.25
Control variables						
Team knowledge on robotics (TKR)	0.50	0.40	1.54	0.38	0.42	0.82
Team previous Lego experience (TPLE)	0.52	0.38	1.88	0.86*	0.47	3.36
Main effects						
Robot identification (RID)				1.38**	0.63	4.85
Team identification (TID)				−0.80*	0.49	2.63
−2 log likelihood		42.62			35.69	
χ^2		4.54			11.47	
df		2			4	
Model sig.		0.10			0.02	
Nagelkerke R^2		0.15			0.35	
Change in Nagelkerke R^2		-			0.20	
Classification accuracy		80%			80%	

Note: All variables, except SGF, were standardized.
$^*p < .10$; $^{**}p < .05$; $^{***}p < .01$.

TABLE 2 Results for teamwork quality

	Teamwork quality (TWQ)											
	Model 1				Model 2				Model 3			
IV	B	SE	LLCI	ULCI	B	SE	LLCI	ULCI	B	SE	LLCI	ULCI
Control variables												
Constant	3.94****	0.08	3.79	4.10	4.03****	0.06	3.90	4.16	4.04****	0.06	3.91	4.16
TKR	0.04	0.08	−0.12	0.21	0.08*	0.05	−0.01	0.18	0.06	0.05	0.03	0.15
PLE	0.09	0.09	−0.09	0.26	0.11*	0.06	−0.01	0.23	0.13**	0.06	0.01	0.25
Main effects												
RID					0.04	0.06	−0.16	0.08	0.01	0.06	0.10	0.13
TID					0.37****	0.05	0.28	0.47	0.33****	0.07	0.20	0.46
SGF					−0.36***	0.02	0.08	0.16	−0.17	0.13	0.43	0.08
Interaction effect												
RID × SGF									−0.42***	0.16	0.72	−0.11
TID × SGF									0.22**	0.10	0.03	0.42
AIC	75.17				41.0				40.16			
df	2				5				7			
Pseudo R^2	0.04				0.62				0.66			

Note: All variables, except SGF, were standardized.
Abbreviations: AIC, Akaike's Information Criterion; RID, robot identification; SGF, subgroup formation; TID, team identification; TKR, team knowledge on robotics; TPLE, team previous Lego experience; TWQ, teamwork quality.
$^*p < .10$; $^{**}p < .05$; $^{***}p < .01$; $^{****}p < .001$.

teamwork quality and that RID and TID can alter the impacts on teamwork quality and performance. The goal of Study 2 was to obtain recommendations derived from practice to mitigate the negative effects of subgroups while enhancing performance and teamwork quality.

5.1 | Sample and data collection

Data were collected through two recruiting firms: CloudResearch (60) and Qualtrics (52), totaling 112 respondents. The sample consisted of individuals who had some experience working directly or indirectly with robots by managing others who worked directly with robots. These individuals worked in various industries: manufacturing and sales, construction, hospital and medical, first responders, warehouse, business services, art and design, financial advising, engineering, computer science, and information technology industries. The mean age was *41.2* years (SD = *11.5* years). There were 68 men, and 44 respondents held 4-year degrees, while 37 reported having professional degrees. The racial breakdown was 99 White, 1 American Indian or Alaska Native, 6 Asian, 2 Black, and 4 Latinx; there were 67 managers and 45 employees.

5.2 | Survey instrument

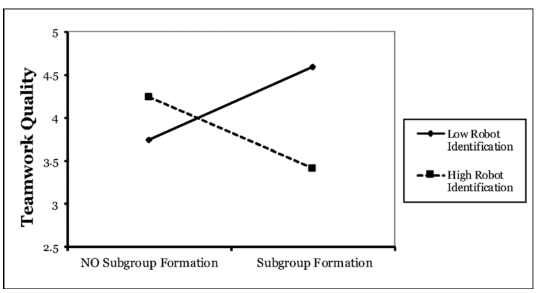
The qualitative online survey consisted of three open-ended questions. The first question had two parts and asked respondents about ensuring good working relationships between human coworkers in human–robot teams. The second question asked respondents to offer recommendations on what they thought would work for effective teamwork in human–robot teams. The mean and the median number of words written per question were *73.62* and *66.50* for the first question and *72.52* and *66.50* for the second question, respectively. Finally, the third question asked respondents to select, from a list, up to three approaches to recommend and explain the reasoning behind their choices, followed by demographic questions. The list was derived from practical recommendations from the literature on subgroup formation (Mäs et al., 2013; Ren et al., 2014; Yilmaz & Peña, 2014). Table 5 demonstrates the number of responses per recommendation item along with the mean and median number of words in written explanations.

5.3 | Data analysis

We analyzed the responses using open coding. The process involved generating codes related to subgroup formation iteratively. The research team initially obtained 83 themes from the data and seven categories, which we constantly revised until theoretical saturation. The research team discussed the emergent findings during the analysis and shared insights. As a result, the data were finally distilled into five major recommendations.

5.4 | Study 2 findings

Findings from Study 2 provide a more in-depth grounding of the sociotechnical implications on the transformation of work as a result of the replacement of workers in various settings. Next, we report the findings from Study 2. The results are organized into five recommendations on mitigating the negative effects subgroups. These include team-building, training employees, improving communication among humans, emphasizing human contributions, and providing leadership. We found that three ways to mitigate the effects of subgroups that undermine performance include training, improving communication among humans, and providing leadership. Each of these speaks to how organizations are engaging or could be engaging in exploring the transformation of work.



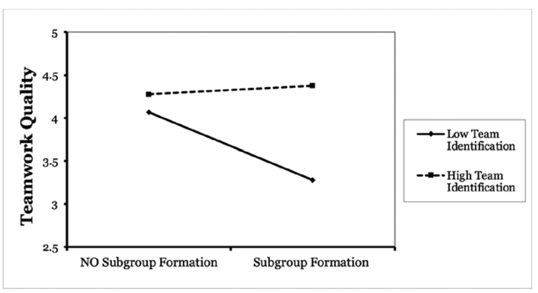


FIGURE 4 Interactions between RID (left) and TID (right) and subgroup formation on teamwork quality

TABLE 3 Results for team performance

IVs	Actual team performance (ATP)											
	Model 1				Model 2				Model 3			
	B	SE	LLCI	ULCI	*B*	SE	LLCI	ULCI	*B*	SE	LLCI	ULCI
Control variables												
Constant	262.27****	7.67	247.22	277.32	256.38****	8.29	240.28	272.49	263.12****	8.94	245.60	280.64
TKR	−10.01	6.83	−23.49	3.30	−10.26*	5.49	−21.02	0.50	−5.20	4.80	−14.56	4.17
TPLE	4.46	7.87	−10.96	19.88	−0.23	8.89	−17.65	17.18	6.23	8.38	−10.20	22.66
Main effects 1												
RID					−12.68	9.68	−31.65	6.29	−14.98*	8.78	−32.19	2.23
TID					−8.44	7.22	−22.60	5.73	14.01	9.61	−4.82	32.84
SGF					25.27†	14.29	−2.74	53.27	3.41	18.08	−32.02	38.84
Main effects 2												
TWQ									−33.89***	12.22	−57.84	−9.93
AIC	478.37				477.89				471.37			
df	2				5				6			
Pseudo R^2	0.03				0.17				0.31			

Note: All variables, except SGF, were standardized.
Abbreviations: AIC, Akaike's Information Criterion; RID, robot identification; SGF, subgroup formation; TID, team identification; TKR, team knowledge on robotics; TPLE, team previous Lego experience; TWQ, teamwork quality.
*$p < .10$; **$p < .05$; ***$p < .01$; ****$p < .001$.

TABLE 4 Hypotheses testing results

	Hypothesis	Results
H1	Robot identification (RID) increases subgroup formation.	Supported
H2	Team identification (TID) decreases subgroup formation.	Marginally supported
H3	RID moderates the impact of subgroups on teamwork quality by decreasing quality when RID is high and increasing quality when RID is low.	Supported
H4	TID moderates the impact of subgroup formation on teamwork quality by increasing quality when TID is high and decreasing quality when TID is low.	Supported
H5	Teamwork quality increases team performance.	Supported

TABLE 5 List of recommendations

Recommendation items	*n* (%)	Average word count (median)
Provide human coworkers with training on working with robots	73 (65.2)	39.14 (38.0)
Conduct team-building exercises involving all coworkers	55 (49.1)	38.29 (39.0)
Facilitate communication between human coworkers	54 (48.2)	35.04 (33.50)
Strong leadership	46 (41.1)	34.78 (29.0)
Emphasize human contributions as a whole	40 (35.7)	40.15 (41.0)
None of the above	6 (5.4)	50.50 (56.0)

5.4.1 | Recommendations for teamwork quality in human–robot teams

Team-building exercises involving all coworkers

Employing team-building activities for ensuring enjoyable human–human relationships was one of the most mentioned recommendations. They included having lunch together, social events like picnics and sports events, and taking coordinated break times with human coworkers. Respondents recommended these because only humans can *eat, feel, and have fun*, whereas robots are not capable of any of those things. Respondents emphasized building a strong human–

human bond while regulating the robots as only a workmate:

> *I think that encouraging employees to get together during lunch or organized company functions would be key to good relationships with human co-workers. Humans are social, and isolating a human with a robot will create a strong bond between the two but not build relationships with the other employees.* (Manager)

Training on working with robots

Training and classes were mentioned significantly, but for different purposes. Specifically, respondents indicated that training and classes would help build good working relationships among human coworkers. For instance, respondents believed that training and classes led their coworkers to realize the limitations of robots as coworkers: robots are not humans and have no human nature.

> *It should be made important in the organization that the robots are just…robots. They have no feelings. This will ensure that… extra time is not being spent on spending "quality" time with the robot employees.* (Manager)

Also, respondents saw the value of training and classes in that better knowledge of robots reduces confusion and unnecessary resentment toward human coworkers when there is a problem.

> *If humans do not understand how robots work, there could be resentment or confusion. It is better if both groups are educated and given the skills to be able to work with each other successfully.* (Employee)

Better communication between humans

The recommendation regarding communication was also mentioned frequently for teamwork quality. Regarding the rationale, respondents believed that the inclusion of robots and subgroups involving them would lead to negative psychological impacts, such as isolation, loneliness, and lack of understanding of human coworkers' values. Several respondents expressed that such negative feelings resonate with their work experience in their feelings of fear of being replaced and seeing their human coworkers replaced. These concerns appear to be valid in human–robot teams because subgroup formation exacerbates the negative feelings at work and, consequently, hurts teamwork quality.

> *Listen to the employees when they have issues. Provide ample incentives to them in order to keep their morale at a higher level. Assure them they are not going to be replaced by robots and that the robots are there to help them perform their daily tasks.* (Employee)

Emphasize human contributions as a whole

Emphasizing human contributions as a whole emerged as a recommendation to meet psychological needs. Specifically, respondents expressed that organizations should not include robots' contributions when evaluating work outcomes and put more value on contributions by humans and collaboration among them. They mentioned that this ensures good relationships among human coworkers by placing value on their work.

> *The organization should recognize humans for their individual contributions, especially the human contributions that cannot be replicated by robots. This would help ease any fears that human workers will experience reduced status or be replaced by robots and help create a team of human workers who see themselves as a more cohesive group of human contributors.* (Manager)

Strong leadership

Effective leaders of human–robot teams are expected to have several abilities: guiding human coworkers to have a clear understanding of the value of robots, building a sound team culture including robots, securing feelings of human coworkers by emphasizing human contributions, and maintaining good working relationships with humans. Also, strong leadership was commonly mentioned both for teamwork quality and team performance, which suggests its importance to the success of human–robot teams.

> *Leadership should be flexible and see when there is a need to switch staff and/or robots to better perform certain tasks. A strong leader will also be necessary to ensure that the human workforce is not intimidated by the robotic workforce.* (Manager)

Overall, the qualitative results indicated several recommendations to reduce the negative consequences of subgroup formation in human–robot teams. Respondents expressed concerns that the inclusion of robots can engender a strong human–robot bond, potentially weakening the human–human bond. Table 6 summarizes the findings from Study 2.

5.4.2 | Recommendations for team performance in human–robot teams

Better communication among humans

The recommendations were categorized into two dimensions: promoting team effectiveness (i.e., performance) and social and psychological outcomes (i.e., teamwork quality). The respondents mentioned facilitating communications among human coworkers. Effective communication among humans enables knowledge sharing and enhanced relationships with human coworkers, which results in better team outcomes.

> *[Having] regular meetings with my human employees to discuss their needs, wants, and concerns [and] addressing any concerns they have working with robots as part of our team. They would be encouraged to make suggestions on how to improve working relationships with robots and how management should handle any conflict between them and robots.* (Manager)

About the role of communication for team performance, respondents mentioned that having better knowledge and skills to solve problems is essential for team success. Respondents emphasized that sharing such understanding and skills among coworkers is beneficial.

> *Make sure that each employee is in communication with other humans so that they know*

TABLE 6 Recommendations for human–robot teams

Outcome dimension	Recommendation	Elaborated reasons
Teamwork quality	Conduct team-building exercises involving all coworkers	For a better human–human bond (more enjoyable relationship)
	Provide human coworkers with training on working with robots	Knowing that robots are not humans and humans are true teammates
		Reducing confusion and resentment between humans when robots break down
	Facilitate communication between human coworkers	Prevent from feeling isolation
		Prevent negative emotions like loneliness and fear of being replaced
		Prevent feeling not valued as a human being (mutual support)
	Emphasize human contributions as a whole	More for feeling valued and contributing to the work (not for better performance)
		Psychological reward (as a valued member)
	Strong leadership	Putting humans and their relationships first
		Can build a team culture
		Ensuring human team members are not intimidated by the robotic workforce
		Making them understand why robots are needed
Team performance	Facilitate communication between human coworkers	To share information on robot knowledge and concerns
		For a better understanding of robots (more effective use of robots)
	Provide human coworkers with training on working with robots	Sharing information and expertise on robots
		For more comfortable feeling on working with robots (more effective use of robots)
	Strong leadership	Guiding the use of robots

how to work as a team to figure out any issues with the robots that might happen. And having that communication would help make that idea work so much easier. (Manager)

Training on working with robots

The recommendation regarding training is in line with the previous recommendation in that respondents believed that expertise in working with robots is vital for team success. Respondents viewed the training and classes as opportunities to share information and expertise in working with robots among human coworkers.

Providing classes and training to human coworkers to improve knowledge of the uses and functionality of robots would help to improve the working relationships of human teammates. It is important for team members to understand how best to utilize robots in their day-to-day work to improve team performance and productivity. (Manager)

Several respondents expressed that the training and classes as organizational support promote human coworkers' confidence, comfort, and positive relationships. Therefore, respondents indicated that the organizational training might ensure better team performance through good working relationships among human coworkers. Both the prior and following quotes suggest the value of training and classes in making more positive relationships among human coworkers.

Teams working with robots in a training environment in a non-live situation to gain confidence and be comfortable with the robots while not feeling uncomfortable making mistakes. The more comfortable team members are playing with it, [the] more comfortable and productive when you go live. (Employee)

Strong leadership

The emphasis on strong leadership was mentioned mainly by respondents who were managers. The rationale behind their recommendation was that leaders of human–robot teams need a clear understanding of the division of labor between humans and robots.

In terms of a team working with a robot, I believe it should start with understanding. Does the team understand how to direct the robot or interact? With clear designations and understanding, team performance and viability is easier to foster and maintain. (Employee)

6 | DISCUSSION

Work teams relying on AI-enabled technology such as robots will increase along with efforts to design them to elicit strong emotional bonds from humans (Vreede & Briggs, 2019). Our results underline the need for a more cautious and considerate approach when attempting to elicit such responses. Next, we discuss implications for theory and work.

6.1 | Theoretical implications

Our findings have several implications for theory and research. First, Study 1 highlighted the overall need to extend theories of subgroup formation to include AI-enabled technologies. Study 1 found evidence of subgroup formation in human–robot teams and its negative impacts. Previous research demonstrated that strong bonds with technology could benefit individuals (K.-K. Kim et al., 2010; Read et al., 2011). Our work goes beyond this by demonstrating whether and when such strong bonds can be problematic. In doing so, we highlight the need for greater theoretical attention. There is a vast body of research on subgroup formation, and it is not clear how much of it is directly applicable to human–robot teams.

Second, Study 1's findings contribute to the existing theories on subgroups. We found that subgroups positively impact teamwork quality when robot identification is low, but these subgroups become problematic when robot identification is high. However, subgroup formation led to increased teamwork quality when TID was high. Our findings identified the particular mechanisms that can help dictate when subgroups are likely to increase/decrease teamwork quality. These findings answer recent calls to identify moderators that constrain the impacts of subgroups (Meyer et al., 2015; Thatcher & Patel, 2012).

6.2 | Work practice implications

First, it is clear that the inclusion of robots can lead to subgroups. The surveyed workers had either already seen evidence of subgroups in human–robot work collaborations or were genuinely afraid they would see them. To address these concerns, many of the workers suggested ways to promote communication, training, and team-building that could all be labeled as approaches to promote TID. This seems to align with our findings from Study 1 regarding the importance of TID in reducing the negative impacts of subgroups. Study 2 goes beyond Study 1 by situating and translating the TID construct to changes in actual work practices.

Second, it was interesting that workers' comments were primarily directed at promoting human relationships rather than reducing human-to-robot bonds. It is possible that the workers' suggestions relating to the promotion of TID could be viewed as ways to reduce RID, but this was not directly suggested by workers. Instead, workers might actually see the value of strong RID and not want to undermine it but instead were more concerned with promoting TID through stronger human bonds. If so, this finding aligns well with Study 1's finding that RID can actually have a positive impact as long as it is coupled with strong TID.

Third, there was an emphasis on leadership in addressing issues associated with subgroups. On the one hand, workers thought that strong leadership was needed to help workers understand the value of robots while promoting strong bonds among human coworkers. On the other hand, managers indicated that strong leadership was needed to determine who should be assigned what tasks. That being said, the importance of leadership in human–robot teams is a relatively unexplored area. Despite this, Study 2's findings seem to imply that human–robot team scholars need to broaden their research agenda to include leadership.

Finally, it seems that as AI and the world of work are reshaping the meaning of work, employees would rather not lose what it means to be a human. More specifically, workers indicated the need to emphasize human contributions as distinct and separate from robot contributions. They also thought it was important to draw clear lines between robots and humans and to remind their coworkers of these distinctions. In doing so, workers latently suggested that organizations must highlight the uniqueness of being a human and instill this value through training, communication, and evaluation. To this point, our results have broader implications for our understanding of how AI reshapes the world of work.

6.3 | Limitations and future research

The study has several limitations. This study employed one method to measure subgroup formation among other possible approaches. We used cohesion between humans and robots to measure subgroups because this aligns with the paper's definition of subgroups. However, previous research has employed many different subgroup measures (Polzer et al., 2006; Thatcher & Patel, 2012). Future research could investigate different measures. Second, while the experimental study found evidence of subgroups, the brief interaction is a limitation. Future research could examine how emotional bonds evolve over time (Björling et al., 2020). Third, robots used in Study 1 were not fully autonomous, representing many of the robots used in workplaces today (i.e., cobots). Future studies could vary the robot's autonomy to determine its importance in understanding subgroup formation and its impacts. Finally, our experimental study was designed to ensure internal validity at the expense of external validity. Future studies should examine the phenomena in field settings to qualitatively unpack the bonding process over time.

7 | CONCLUSION

In this paper, we sought to extend our understanding of the changing relationships among workers, work practices, and robots—one specific type of AI. As physically embodied AI, robots are able to elicit strong emotional bonds from humans, leading to subgroups in human–robot teams. This study sought to understand the implications of subgroup formation and propose changes to work practices to accommodate these implications better. Overall, this study contributes to the literature on artificial intelligence and the future of work.

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