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Walking on “Mars”: Gendered Group Processes in Space Analog Missions

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Abstract

Most research on mixed-gender teams in space analog environments focuses on individual-level variation and overlooks structural causes of inequality. Status characteristics theory posits how socially recognized traits, such as gender, contribute to the formation of informal hierarchies by denoting perceived levels of competence to group members. We investigated gender as a status characteristic in groups in space analog environments. We used data from the Mars Desert Research Station (MDRS) and hypothesized that women crew members are less likely than men to be selected to participate in simulated extravehicular activities during a Mars simulation at the MDRS. We used reports and biographies from 30 randomly selected crews ($n = 177$) posted on the MDRS website to construct our dataset and multilevel generalized regression models to test our hypothesis. Women crew members were 6% less likely to participate in simulated extravehicular activities than men, controlling for crew role, education, and other factors. Our study shows that gender acts as a status characteristic and influences group decisions in crews in space analogs. These results highlight the need for more studies on interactional inequalities in preparation for a long-term human spaceflight.

Keywords: status characteristics, mixed-gender team, space analog environment, group processes, gender, Mars Desert Research Station

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Introduction

In a few years, the first woman will walk on the moon, and the first spaceship to Mars will no doubt have both female and male astronauts on board. Mixed-gender crews in space and similar environments are more efficient, cohesive, and have better overall group climates (Bishop, 2004; Kahn & Leon, 2000). However, gender differences can also lead to additional tension within crews (Kanas, 2015; Kring & Kaminski, 2012; Sandal et al., 2007). For example, studies conducted at Antarctic stations show that women are seen as outsiders, and constantly need to prove their competence to be accepted by their male colleagues (Nash et al., 2019; Sarris, 2017; Sarris & Kirby, 2005).

In most task group situations, controlling for other factors, women are perceived as less competent than men with similar capabilities (Ridgeway, 2009). These views can have real impacts on women’s self-assertion, their influence, and how others evaluate them. The biasing impact of gender can be small during one group encounter; however, cumulative comparable interactions have consequences, and can result in substantially different outcomes for otherwise equally competent men and women (Ridgeway & Correll, 2004). Moreover, the discrepancy between actual and perceived abilities within crews working in extreme environments, such as within space contexts, could develop into more dire consequences than mere group tension.

Much more research is needed to investigate the link between gender and perceived competence within teams in space and other isolated, confined, and extreme environments. The majority of extant research uses the lens of individual psychology, and does not address gender in the context of broader structural inequalities. We aim to begin filling this gap by investigating crews as embedded in society-wide belief systems about gender and perceived competence. To our knowledge, this is the first such study.

We explore mixed-gender crews that live and work in a space analog environment at the Mars Desert Research Station (MDRS). We use two theories—status characteristics theory and legitimation theory—from the expectation states framework (Wagner & Berger, 2002) to motivate our research. Status characteristics theory (SCT) explains how society-wide social inequalities, such as those based on gender, affect group-level interactions (Ridgeway, 1991). Legitimation theory delineates how informal status hierarchies become accepted as legitimate within a group (Lucas, 2003). Combining these two theories to hypothesize about group processes within these contexts contributes to expectation states research as well. We discuss how gender differences may not only create disparities in behaviors directly related to task completion,

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which is explained by SCT, but may also affect distributions of acts not associated with group task completion, which we use legitimation theory to conceptualize.

In particular, we focus on the potentially gendered patterns in participation in extravehicular activities (EVAs) during Mars simulations at the MDRS. Crews are asked to choose EVA teams based on members' competence; contrary to a real space mission, the mission control has no decision power in the selection process. We predict that men are more likely than otherwise similar women to be selected for participation in EVAs. We discuss gendered group dynamics in an attempt to foster future research and intervention strategies to improve women's experiences and group decision-making in space and space analog environments.

Theoretical and Empirical Background

Mars Desert Research Station

In an ideal world, researchers interested in groups in space would study groups in space. But in reality, astronauts' data are hard to access, sample sizes are very small, and the only place to study such groups is the International Space Station. Thus, researchers rely to a great extent on studying groups in other places that share some characteristics with spaceflight—space analogs. Most space analogs share the following characteristics: (1) high reliance on technology for life support and tasks; (2) social and physical isolation; (3) high risk and dangerous consequences of failure; (4) high physiological, psychological, social, and cognitive demands; (5) importance of human–human, human–technology, and human–environment interaction; and (6) critical importance of team coordination, cooperation, and communication (Bishop, 2012). Space analog studies are conducted in places that already exist for another purpose (for example Antarctic research stations) or in specifically built facilities (Bishop, 2012; Caldwell, 1990; Harrison et al., 1991).

The MDRS is a space analog owned and operated by the Mars Society, a space advocacy group. The MDRS has been functioning since 2001; it operates November through June. Crews of about six people stay in relative isolation and confinement for an average of two weeks to simulate human operations on Mars. To date, over 220 crews (approximately 1500 people) have participated in the MDRS simulations.

A typical simulation period lasts two weeks. During this time, crews are living as if on Mars. For example, crews use above-ground walkways to get between buildings on the MDRS campus, and avoid going outside unless conducting a simulated EVA. All crews are required to submit daily reports to the Mission Control. The reports are posted online at mdrs.marssociety.org, and are available to the general public.

A fixed number of roles are available for the crew members: Commander, Executive Officer, Health and Safety Officer, Engineer, GreenHab Officer, Scientist/Geologist/Biologist, Astronomer, Journalist, and Artist/Artist in residence. Crews are formed in two ways: potential crew members can individually apply for a role, and then be assigned into a crew by the MDRS administration, or crews can form ahead of time and apply as a whole group. Regardless of individual or group application, potential crew members must state their motivations for joining a simulation and their skill sets, which allows administrators to match them to their best-fitting role. All crews have the same set of roles.

Simulated EVAs are an integral part of all MDRS simulations. During an EVA, individuals put on simulated space suits and leave the MDRS quarters to perform various tasks on "Mars" surface. According to the MDRS handbook, every EVA should serve a purpose, but cannot be the main focus of the simulation. Usually, no more than two EVAs are permitted daily (engineering EVAs, which are mainly maintenance of the hab, are excluded from this restriction). Crews are asked to form EVA teams in accordance with specific objectives that need to be achieved. Crews decide on the final participant list and then contact the Mission Control with the list of participants and the EVA plan to get final permission[1].

Status Characteristics and Legitimation Theories

We use SCT and legitimation theory frameworks to explain gender differences in EVA participation during a simulation in the MDRS. SCT describes how beliefs about social inequalities from wider society inform expectations about group members' competence to perform, and how these expectations, in turn, create social hierarchies and behavioral differences within task groups. The theory predicts that groups who are task-oriented (that is, groups who are primarily motivated to complete a shared goal for which they know that there are successful and unsuccessful outcomes) and collective-oriented (groups whose members take all other group members' opinions, ideas, and even nonverbal gestures into consideration during task completion) will form informal group hierarchies (Berger & Webster, 2006; Webster & Walker, 2014).

SCT has two important concepts: *status characteristics* and associated *performance expectations*. A *status characteristic* is based on cues that reveal one's belonging to a

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[1] According to the MDRS handbook, predetermined EVA schedule, such as assigning EVA slots ahead of the simulation regardless of actual tasks or taking as many people to each EVA as want to go, is discouraged. However, training focusing on EVA team selection based on competence was instituted only in 2016 and crews that participated in earlier seasons were not strictly required to focus on selecting EVA team members based on perceived task-related competence. Theoretically, this can mean that pre-2016 diffuse status characteristics (gender in our case) could have had more influence in EVA team selection process than task-related skills. To account for that, we introduced a dummy variable in our models.

specific social category, for example being of different gender, occupation, or race. A set of widely shared beliefs about relative competence and ability are attached to status characteristics. Status characteristics can be specific or diffuse. A *specific status characteristic* is a characteristic directly related to the task at hand and has beliefs about task-related competence and ability attached to them (Correll & Ridgeway, 2006): if a team needs to write a code, an experienced software engineer will be seen as having more competence and ability at this specific task than a novice software engineer.

A *diffuse status characteristic* is not related to a specific task, and is associated with more general performance expectations (Berger & Fişek, 2006; Correll & Ridgeway, 2006). Gender is a diffuse status characteristic (Ridgeway, 1991; Ridgeway & Diekema, 1992; Ridgeway & Smith-Lovin, 1999): for instance, men are often viewed as being more competent in general compared with women, especially on tasks considered "male-centric" (Dovidio et al., 1988), such as science-related endeavors.

When group members are working on a task, *status generalization* occurs: differences in individuals' status characteristics form *performance expectations* (situational beliefs about performance on the task at hand), and these performance expectations establish observable differences in influence among group members (Berger & Webster, 2006). It is an "out-of-awareness" process based on hunches and anticipations about one's capacity in a given task. It leads to the formation of a mutual status hierarchy, where individuals with higher perceived competence occupy higher positions and have more influence in the group (Ridgeway & Walker, 1995).

In sum, members of task groups anticipate the quality of contribution from participants (including themselves) based on their perception of their abilities. Cultural beliefs, attached to observable status characteristics, contribute to group members' perceptions of competence. A mutual status hierarchy forms, where group members believed to be most competent have more influence at the task at hand. This hierarchy manifests in observable power and prestige behavior: individuals with higher status use power and prestige behavior to elicit deference from lower status individuals. SCT also uses formal propositional statements to describe with precision the underlying mechanisms for how status characteristics activate status generalization, how performance expectations become attached to these characteristics, and how the observable behaviors would result from the organizing process (see Berger et al. (1977) for the formal propositions, mathematical equations, and lists of observable behaviors traditionally examined to detect status generalization).

Once this social hierarchy is formed, group members choose individuals to assume leadership roles. As explained by legitimation theory (Lucas, 2003), these choices are biased by their understanding of whom within the group has more competence, which was established through status generalization. Legitimation theory suggests that once a group finds it right and proper to allow some group members to garner more influence and other social advantages as compared with others, then other actions will be determined by this status order (Berger et al., 1998; Zelditch & Walker, 2018).

Gender is a diffuse status characteristic, and its influence on status generalization depends on a context. Women and men do not differ in their engagement in power and prestige behavior when they are in same-gender task groups (Shelly & Munroe, 1999; Wagner & Berger, 1997; Walker et al., 1996; Webster & Walker, 2017); however, in mixed-gender groups, men tend to have more influence than women, especially in masculine-typed tasks (Dovidio et al., 1988).

In a mixed-gender group, choice of leader will be affected by gendered group hierarchy. Men are perceived as being more competent at the original group tasks and therefore more competent in general, and those perceived as having more competence are also viewed as having the potential to be better leaders. Lucas (2003) demonstrated this by assembling mixed-gendered task groups in a laboratory situation. He had study participants work in task- and collective-oriented groups, and then he prompted them to have a collective discussion for choosing the group leader. Male leaders were chosen far more than female leaders.

Akin to leadership selection, we argue that selecting crew members to participate in an EVA is also the result of the social hierarchies created within mixed-gender groups. Crews that participate in MDRS simulations are task- and collective-oriented. Each MDRS crew member has an official role, with accompanying work expectations: Commander, Engineer, etc. But a newly developed informal group hierarchy, based on status generalization processes, might not mirror the formal, assigned role organization within a crew. Once this informal group hierarchy emerges, it tends to be stable within groups that have permanent members that continue to work together (Cohen & Zhou, 1991). Accordingly, informal hierarchy based on status generalization processes will continue to influence crew interaction throughout simulation.

Those who are chosen from within the group to participate in an EVA would first be perceived as competent on specific tasks, then be considered more competent in general, and finally be perceived as being more capable for EVA missions. If gender is the diffuse status characteristic behind these processes, then men are more likely than women to be chosen to participate in an EVA.

We do make two notes, however. Status generalization is a nonconscious group process that happens out of group members' awareness and all group members subscribe to this system of inequality: lower-status individuals, in this case, women, will defer to their male counterparts.

Male group members do not need to perform any dominance behaviors to spur this process.

The second note is that if group members differ on other status characteristics—ones that imply general competence—then those will also be detected as a part of the status generalization process. To detangle effects of a single status characteristic we need to study the status generalization process in a controlled experimental environment. However, studies conducted in real-life settings are still able to detect effects of status characteristics in group interactions (Bianchi et al., 2012; Cohen & Zhou, 1991): in other words, we do not expect gender to be the single variable explaining unequal participation in EVAs, but we expect it to be a statistically significant contributor.

A Note On Tokenism Framework

An alternative explanation of group-level gender inequality can be found in the tokenism framework (Kanter, 1977). This theory attributes inequality in work groups to token status; that is, a low proportion of members from one social group in comparison with dominant groups. Tokens tend to have worse experiences than non-tokens. The original scholars from this framework focused on proportional representation, and suggested that including more women within male-dominated workplaces can improve their positions. Later studies (Watkins et al., 2018; Yoder, 1991) showed that token individuals have a range of experiences depending on a variety of situational and contextual factors, such as the gender and race of an individual. We include measures that reflect crews' gender composition, such as proportion of women in a crew and gender of crew commander, to serve as indicators of the phenomenon.

Hypothesis

Based on SCT and legitimation theory, we predict that when crews choose participants for EVAs, on average, men will be chosen more often than women because they will be nonconsciously perceived as more competent than women. We test the following hypothesis:

> H_1: Men will have a higher EVA participation ratio, in comparison to women, all other things being equal.

Method

Sampling

All crews are required to submit daily reports to the Mission Control. All reports are posted online at mdrs.marssociety.org, and are available to the general public. For this study, we used daily reports and biographies from 30 randomly selected crews that participated in the simulation between 2001 and 2018. We excluded crews that had returning members who had been already coded as members of other crews to avoid having the same individuals appear twice in our dataset. We used a random number generator to generate 30 numbers between 1 and 189 (this was the number of the last crew at the time of data collection in spring 2018). If a crew that was selected by the random number generator did not satisfy these requirements, we selected the next crew. Our crew selection is presented in Table 1.

Data

We used crews' reports to get information on crew members' participation in EVAs. We recorded the total number of EVAs conducted by each crew. From this number, we calculated each individual's EVA participation rate as a percentage of total crew EVAs.

We extracted participants' gender (assumed), their role in the crew, their level of education, and whether or not they had prior participation in the MDRS or a similar simulation from crew biographies. Using these data, we then calculated two additional crew-level variables: the gender of crew commander and the percentage of women in each crew. Table 2 summarizes our dataset.

Dependent Variable: EVA Participation Rate

We counted the number of times that each individual participated in a simulated EVA. Some reports listed EVA participants; others mentioned their names in narrative descriptions. We also counted the total number of EVAs that the individual's crew performed. From these, we calculated a participation rate (as a percentage) for each

Table 1
Crew sample selection.

Field season (year)	Number of crews selected
#1 (2001–2002)	
#2 (2002–2003)	4
#3 (2003–2004)	3
#4 (2004–2005)	2
#5 (2005–2006)	1
#6 (2006–2007)	
#7 (2007–2008)	
#8 (2008–2009)	
#9 (2009–2010)	
#10 (2010–2011)	5
#11 (2011–2012)	1
#12 (2012–2013)	3
#13 (2013–2014)	1
#14 (2014–2015)	4
#15 (2015–2016)	3
#16 (2016–2017)	2
#17 (2017–2018)	1
TOTAL	30

Table 2
Data summary.

	Variable	Reported	%	Mean	SD	Min.	Max.
Individuals (n = 177)	EVA participation rate			49.9	16.7	3.3	93.3
	Gender						
	Woman	63	36				
	Man	114	64				
	Role in the crew						
	Commander	30	16.9				
	Executive officer (XO)	22	12.4				
	Engineer	40	22.6				
	Scientist	47	26.6				
	Media/communication	18	10.2				
	Other	20	11.3				
	Education						
	High school diploma	55	31.1				
	Bachelor's degree	69	39				
	Graduate or professional degree	53	29.9				
	Previous simulation experience						
	Yes	16	9				
	No	161	91				
Crews (k = 30)	Woman commander						
	Yes	11	36.7				
	No	19	63.3				
	% of Women			35.6	12.3	16.7	60
	Participated in 2016 or later						
	Yes	3	10				
	No	27	90				

Source: MDRS.

individual. As shown in Table 2, the mean rate was 49.9% (SD 16.7%). The maximum rate was 93.3% and the minimum rate was 3.3%. The participation rate approximates a normal distribution.

Independent Variables

Gender

This was coded as a binary variable (woman = 1) derived from crew biographies. The majority of our sample were men (64%).

Role in the Crew

Role was coded as a categorical variable derived from crew biographies. As previously mentioned, a fixed number of positions are available for the crew members: Commander, Executive Officer, Health and Safety Officer, Engineer, GreenHab Officer, Scientist/Geologist/Biologist, Astronomer, Journalist, Artist. In the case of a crew member occupying two positions, we assigned the position that was mentioned first in the biography. For example, if someone is an Engineer and an Executive Officer, this person was noted as an Engineer; or if someone is a Health and Safety Officer and also a Scientist, they are coded as Health and Safety Officer. All scientists (e.g. Scientist, Biologist, Geologist) were coded as Scientist. We coded Journalist, Artist in Residence, Science Communicators as Media/Communications Officer. Other less common roles, such as Astronomer, Green Hab Officer, Health and Safety Officer, were coded as Other. See Table 2 for the distribution of roles in our sample.

Education

We retrieved this information from the crew biographies. We coded the level of education into three categories: High School Diploma, Bachelor's Degree, and Graduate or Professional Degree. Individuals' level of education was listed in most biographies. In a few cases when education was not explicitly mentioned, we assigned High School Diploma to undergraduates, and a Bachelor's Degree to people working in a field where an entry level position commonly requires a college degree. Almost a third of our sample (31%) were undergraduate students with high school diplomas. Thirty-nine percent had a bachelor's degree, and the rest (30%) had a graduate or professional degree.

Previous Simulation Experience

We coded this as a dummy variable equal to 1 if it was mentioned that the individual has prior participation in a space analog simulation. Only 9% of our sample had previous experience in a space analog environment.

Woman Commander

We created a crew-level dummy variable equal to 1 if the crew had a female commander. Of the crews, 63% (19) were led by a male commander, and 37% (11) by a female commander.

Percentage of Women

This was coded as a continuous, crew-level variable. We calculated the percentage of women in each crew. On average, there were two women in every six-member crew.

Statistical Model: Multilevel Generalized Regression

To test our hypothesis that men will have higher in-group status, all other things equal, we used multilevel generalized linear regression models. We used a linear regression model as our dependent variable is normally distributed (mean = 49.9, SD = 16.7) because we transformed the raw count of EVA participation to the ratio of EVA participation. Our dataset consisted of 177 individuals that are nested in 30 crews. We used the following model: γ_{00} denotes the intercept, γ_{10} through γ_{40} are level-1 (individual) predictors, and γ_{01} through γ_{03} are level-2 (crew) predictors. $u_{0j} + e_{ij}$ represents an error term accounting for different crews.

Equation 1. Multilevel generalized linear regression model predicting EVA participation

$$\begin{gathered} EVA\,participation = \gamma_{00} + \gamma_{10}\ gender_{ij} + \gamma_{20}\ role \\ + \gamma_{30}\ education + \gamma_{40}\ previousexperience \\ + \gamma_{01} 2015/2016 + \gamma_{02}\ womenration + \gamma_{03} \\ womancommander + u_{0j} + e_{ij} \end{gathered}$$

We checked for collinearity. Generalized variance-inflation factors for each independent variable varied from 1.1 to 1.6, which was in the acceptable range and suggested a slight correlation that was not strong enough to warrant corrective measures.

Results

We started by running an empty random intercept model to estimate the proportion of variance in the EVA participation that is accounted for by different crews. Intraclass correlation coefficient was 0.13, which means that 13% of variation in EVA participation can be attributed to different crews.

In our subsequent models, we allowed the intercept to vary between crews to capture crew-level variations that were not observed in our data. We fixed the slope coefficients because we were looking for general, and not crew-specific, effects of our independent variables.

We included level-1 and level-2 predictors, one by one. We used ANOVA (analysis of variance) to compare each new model with the previous simpler model to ensure that added predictors improve model fit (as measured by Akaike information criterion, AIC), and did not just artificially boost R^2.

Table 3 summarizes the multilevel regression coefficients for our models. We include the empty model as well.

Overall Model Fit

Model 0 is an empty model, with only a random intercept as a predictor for EVA participation ratio. By allowing the intercept to vary, we account for different crews and 13% of the total variation in EVA participation ratio. When we add only gender to the model (*Model 1*), the predictive power increases by 2% (total $R^2 = 0.15$), but the overall model fit does not improve. Adding education and crew role measures significantly improves both the model fit and predictive power of the model: total R^2 of *Model 3* is 0.23, and its AIC is statistically significantly lower than simpler models' AIC. Other independent variables—previous simulation experience, woman commander, woman ratio in the crew, and whether a crew participated in the 2015/2016 field season and later—do not improve model fit as measured by AIC differences. The R^2 does increase (to 0.25 in *Model 7*), but only because these models are more complex and each new independent variable reduces error variance. Our best fitting model (*Model 3*) explains 23% of all variance in EVA participation. While this number may seem low (77% of variation is not explained by our model), our aim is to test a theory, and not to make predictions. A low value of R^2 suggests that there are—unsurprisingly—a host of other factors that affect EVA participation in addition to those that we specified. As we are not aiming to account for all of the possible factors, but merely establish a relationship between particular variables, we use R^2 in conjunction with other fit measures to compare our models, and not as an absolute explanatory measure (see Moksony (1999) for a discussion of R^2 in social science research).

Independent Variables

Gender

As a sole independent variable, gender does not have statistically significant association with EVA participation ratio ($p = 0.07$) and adding this variable does not improve model fit in comparison to the empty model. Comparison with subsequent *Model 2* and *Model 3* shows that additional variables (education and crew role) improve model fit and do not dramatically change gender coefficient estimate or its direction. When we compare the residual standard error (RSE) of *Model 1* to *Model 3*, we see that error variance is lower in the latter (15.51 to 14.96). Additional independent variables absorb some of the error

Table 3
Multilevel regression coefficients for EVA participation ratio.

	Model 0	Model 1	Model 2[a]	Model 3[a]	Model 4	Model 5	Model 6	Model 7
(Intercept)	49.90***	51.50***	55.05***	48.69***	47.74***	47.95***	45.53***	45.71***
		(1.84)	(2.71)	(3.91)	(4.10)	(4.27)	(5.90)	(5.93)
Level-1 variables								
Woman		−4.5	−5.13*	−5.92*	−6.27*	−6.25*	−6.52*	−6.48*
		(2.47)	(2.45)	(2.56)	(2.61)	(2.61)	(2.65)	(2.65)
Education (ref. = High School)								
College Degree			−7.39*	−6.71*	−6.82*	−6.83*	−7.03*	−6.96*
			(3.06)	(3.07)	(3.08)	(3.09)	(3.12)	(3.13)
Grad/Prof Degree			−1.47	−0.16	−0.36	−0.45	−0.79	−1.03
			(3.39)	(3.36)	(3.37)	(3.39)	(3.44)	(3.46)
Role (ref = Commander)								
XO				8.26	8.81*	8.75*	8.63*	8.54
				(4.26)	(4.32)	(4.32)	(4.33)	(4.33)
Engineer				2.96	4.03	4.05	3.92	4.1
				(3.76)	(4.02)	(4.02)	(4.03)	(4.04)
Scientist				10.68**	11.81**	11.81**	11.66**	11.75**
				(3.60)	(3.89)	(3.90)	(3.91)	(3.91)
Media/Comm.				2.87	3.94	3.91	3.99	3.89
				(4.60)	(4.82)	(4.83)	(4.84)	(4.84)
Other				10.21*	11.41*	11.34*	11.35*	11.31*
				(4.46)	(4.72)	(4.73)	(4.73)	(4.73)
Previous simulation					3.61	3.58	3.41	3.57
					(4.68)	(4.70)	(4.71)	(4.72)
Level-2 variables								
Woman commander						−0.48	−1.11	−1.33
						(3.27)	(3.47)	(3.5)
Women ratio							8.45	6.26
							(13.99)	(14.35)
2015/2016 and later								3.37
								(4.17)
N	177	177	177	177	177	177	177	177
N (crew)	30	30	30	30	30	30	30	30
AIC	1496.89	1491.96	1480.94	1455.86	1452.34	1450.14	1444.66	1441.32
BIC	1506.42	1504.67	1499.99	1490.80	1490.46	1491.43	1489.13	1488.97
RSE		15.51	15.28	14.96	15.11	15.01	15.00	15.00
R^2 (fixed)		0.02	0.05	0.11	0.11	0.11	0.11	0.12
R^2 (total)	0.13	0.15	0.18	0.23	0.22	0.23	0.24	0.25

[a] The model's AIC index is significantly smaller ($p < 0.05$) than the previous simpler model.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

variance of the initial model. In other words, the model that uses only gender to estimate EVA participation ratio is too simplistic, but gender is a statistically significant predictor ($p < 0.05$) in a more complex model (there is also a sign of suppression effect: the slope changes from −4.5 to −5.92).

When we account for education and role, women crew members will participate in 6% fewer EVAs than men ($p < 0.05$, SE = 2.56). These estimates do not change much after we add more control variables, and the effect of gender stays consistently statistically significant at $p < 0.05$ level. *Therefore, our hypothesis that men will have a higher EVA participation ratio, in comparison to women, all other things being equal, is supported.*

Education

Level of education is related ($p < 0.05$) to the EVA participation ratio. In comparison to crew members with only a high-school diploma, individuals with college degrees went to 6.71% (SE = 3.07) fewer EVAs, on average. This result suggests that college students, who comprise a big part of MDRS simulation participants, are more likely to participate in EVAs than people who already graduated from college, but do not have graduate or professional degrees. There was no statistically significant difference in EVA participation between college students and individuals with graduate or professional degrees.

Role

In comparison with the Commander, the crew Scientist is statistically significantly ($p < 0.01$) more likely to participate in EVAs. When we account for gender and education, a Scientist is likely to participate in 10.68% (SE = 3.60) more EVAs than a Commander. This number increases to almost 12% once we account for previous simulation experience. Executive Officers and crew members taking roles that are grouped into Other are also more likely than a Commander to participate in EVAs. All crew role coefficients are positive, suggesting that it is very unlikely for a Commander to participate in more EVAs than other crew members.

Other Independent Variables

Other independent variables (see *Models 4–7*) do not have a statistically significant relation with the dependent variable. Neither the gender of Commander nor more women on the crew lead to closing the EVA participation gap between men and women in MDRS teams. Previous simulation experience also does not matter by itself.

In sum, we found that gender, education, and role in the crew are significantly related to EVA participation.

Discussion and Conclusion

The aim of this study was to examine gender in a space analog environment from a structural perspective. We used SCT and legitimation theory from the expectation states theoretical framework. Our results suggest that gender operates as a diffuse status characteristic and influences status generalization processes in crews that live and work in space analogs. Gender is a poor predictor of EVA participation by itself, but it becomes statistically significant when we control for other status characteristics, such as formal roles and additional social distinctions.

Our study has important limitations. EVA participation is an outcome of group decisions that we did not directly observe, and the effects of gender, level of education, and crew role can be due to perceived competence, or due to actual differences in performance. Usually, status processes are studied in experimental settings where researchers can control all the social information and isolate the status generalization processes. It is impossible to do that using secondary data from a natural setting, and we agree that actual competence can overlap with the effects of status characteristics on task outcomes. Because of these limitations, we are not suggesting a *causal* relationship between status characteristics and EVA participation rates. Nevertheless, being a woman is associated with lower involvement with EVA operations than men, thus constraining opportunities for many crew members. Importantly, our results showed that individual-level remedies, such as inclusion of more women in the crew or gender of the Commander, do not close the gender participation gap in EVA teams.

To our knowledge, this is the first study that uses the expectation states theoretical framework to study mixed-gender group dynamics in a space analog environment. This project contributes to a growing pool of research that explores status generalization conducted outside of experimental settings. It shows that diffuse status characteristics are persistent in long-term groups in space analog environments. It also confirms our amalgamation of SCT and legitimation theory to predict if status hierarchies based on gender affect acts other than those directly related to task group completion, such as the choice of who inhabits a leadership role. If such hierarchies were nonexistent, then no gender differences in EVA crew choice would occur. However, since one of the behavioral outcomes of task group completion is EVA crew composition, we can posit that status generalization shapes the groups' selections for whom constitutes EVA teams.

In more practical terms, we showed that gender continues to matter in situations where decisions should be made purely on the basis of competence. EVAs are meant to help crews to achieve their simulation research goals, and our results do confirm that crew scientists are more likely to participate in them, as are undergraduate students and graduate degree holders.

Gender bias in EVA participation matters for two reasons. First, these results are in line with previous findings that highlight structural gender inequality in space analogs (Nash et al., 2019; Sarris, 2017; Sarris & Kirby, 2007). Interactional group-level inequalities contribute to persistent gender gap in science, technology, engineering, and mathematics (Kanny et al., 2014; Sax & Newhouse, 2018; Wang & Degol, 2017). It is possible that early career experiences (a third of our sample were undergraduates) contribute to fewer women pursuing careers in the space sector because of these interactional barriers to full participation. However, more research is needed to assess this particular link.

Second, the persistence of gender inequalities within crews in space analogs is worrisome due to the possibility of obstructing crew members who may have the actual (instead of perceived) competence to solve problems. While space analogs are less deadly and dangerous than an actual space setting, our findings show a critical need to study how structural level inequalities bias group interaction and decision-making in such environments. Group decisions should be the result of group members who organize themselves based on objective capabilities, not cultural preconceptions of who has competence and who has not.

On a more positive note, once we know that gender influences status generalization processes, we can turn to theory-driven and empirically tested intervention methods to alleviate its effect, such as multi-ability status treatment (Cohen, 1994). Groups, while still in the formation stage, are taught to organize tasks by recognizing the different capabilities required to complete them. Tests of this treatment have shown that groups, who would otherwise make biased decisions, become more efficient and effective at solving problems (Cohen & Lotan, 1997).

Additionally, future studies should examine a broader array of diffuse status characteristics, for example, race, ethnicity, or nationality, and how these social distinctions prompt status processes and consequential decision-making in teams in space and space analog environments. If status generalization results from these status distinctions, it too can be removed to create more inclusive work environments.

In conclusion, the present study focuses on structural gender inequalities in crews that participate in MDRS simulations. By utilizing SCT and legitimation theory, we showed that gender operates as a diffuse status characteristic in crews that live and work in a space analog environment. Simulated EVAs are an integral part of every simulation, and their primary goal is to contribute to overall mission objectives. While crews are asked to select EVA participants in accordance with their competence, men are more likely than otherwise similar women to be selected as EVA participants. The most important contribution of this study is that it highlights how structural gender inequality biases decision-making in space analog environments.

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