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Exploring Personality and Stress during Communication Delays in Simulated Spaceflight Missions

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To date, there are no studies exploring how an individual's unique personality profile predicts their response to the stresses and challenges of communication delays on Long Duration Exploration Missions (LDEMs). When exploring astronaut selection for future LDEMs, the Big Five personalities have been identified as a relevant model of personality and one of the preferred models among NASA scientists. This study examined whether personality predicts stress levels when experiencing communication delays during simulated spaceflight missions. A predictive correlational design explored the relationship between personality and stress levels while experiencing a 2-minute one-way communication delay during a simulated Mars mission. Personality included the Big Five personality traits (extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience) and locus of control (LOC). Stress levels were reflected by the difference in stress (DS) scores measured using a stress Visual Analog Scale (VAS). There were significant relationships between conscientiousness and extraversion, both of which were significant predictors of DS scores. LOC was also significantly associated with DS scores. Conscientiousness and extraversion predicted stress when experiencing communication delays. LOC was also identified as a predictor of stress levels. These findings benefit the characterization of crew selection and composition of future spaceflight teams. They also promote a multi-trait, multi-method approach to astronaut selection.

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Introduction

Scientists and experts have established that the mission control center (MCC) dynamic of future long-duration exploration missions (LDEMs) will be significantly different from what it is today. Missions to the Moon, Near-Earth orbit, and Mars will present logistical challenges, such as delayed communication between ground control and crew, ranging from a couple of seconds (s) to up to 20 minutes (Palinkas et al., 2017). A human expedition to Mars will involve increasing communication delays between the crew and MCC, rendering normal voice communication impossible within weeks of departing Earth. As crews venture deeper into outer space, the pre-established relationship between the crew and ground/MCC is critical, as they will be the only lifeline crews will have back to Earth. Under these circumstances, effective and clear communication between crewmembers and MCC will be essential for completing mission objectives and maintaining mission safety (Kanas & Manzey, 2008). Without the appropriate support from MCC, communication delays in future missions could negatively impact crewmember performance and behavior (Kanas & Manzey, 2008). Due to the lack of LDEMs to date, there is limited knowledge of how communication delays impact individual crewmembers, and the necessary countermeasures for their mitigation still remain largely unknown (Kintz & Palinkas, 2016).

To date, no studies have explored communication delays from an individual differences perspective, specifically exploring how an individual's personality profile predicts their response to the stresses and challenges of asynchronous communication of varying delays. An initial protocol for an ISS study (Palinkas et al., 2017) investigating the effect of communication delays on well-being and performance planned to include personality traits such as LOC as moderating variables; however, this was ultimately forgone due to concerns expressed by the astronaut office (AO) about the astronaut's willingness to answer specific types of information in a standardized form (Palinkas et al., 2017). Palinkas et al. (2017) would have been the first study to investigate this dynamic. One way to determine which applicants may be unqualified or unsuitable for future deep exploration missions is by measuring different personality constructs.

LOC is defined as an individual's perceived level of control over their situation and experiences that shape their lives (Rotter, 1966). Individuals with an internal LOC believe that events result from their own behavior and actions, whereas individuals with an external LOC believe that events result from an external environmental factor. Although less studied in the spaceflight domain, LOC is a popular construct with important implications in both aviation and military research (e.g., Hunter, 2002; Hunter & Stewart, 2012; You, Ji, & Han, 2013). In a review of predictors and other factors that could contribute to behavioral maladjustment and psychiatric conditions in future spaceflight missions, locus of control was described as one of the components necessary for resilience (ability to sustain or bounce back from different stressors). Specifically, resilient crewmembers of future missions would be those who possess an internal locus of control (Slack et al., 2016). One of the few spaceflight studies exploring LOC was

conducted at the Mars-500 experiment, where Russian cosmonauts spent 520 days in group isolation and confinement (Solcova & Vinokhodova, 2015). Among the many conditions simulating LDEM, cosmonauts experienced communication delays varying from 8 to 736 seconds with MCC. When comparing baseline data with follow-up data, LOC was found to become more internal in four of the five cosmonauts, which was thought to reflect personal growth (Solcova & Vinokhodova, 2015). Given cosmonauts' preference for working autonomously, it is expected that individuals with more internal LOCs would be more effective at coping with periods of asynchronous communication in LDEM compared to those with more external LOCs.

Among other existing personality theories and models, one of the preferred models for astronaut selection is Costa and MacCrae's (1992) Five-Factor Model (Landon et al., 2017), also referred to as the Big Five personalities. This theoretical model proposed that five core personality traits serve as the building blocks of personality: extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience. Extraversion (the opposite of introversion) is the level of sociability and outgoingness. Agreeableness is characterized as the degree of interpersonal trust and altruism. Conscientiousness refers to the level of sensibility in decision-making, organization, and self-discipline. Neuroticism is an individual's emotional stability and tendency to experience psychological distress. Finally, openness to experience is proactively seeking to try new things (Costa & McCrae, 1992). In addition, each personality trait represents a range between two extremes. For example, most individuals will score on a continuum somewhere between extraversion and introversion. Furthermore, the research suggested that the five factors are relatively stable and endure throughout adulthood (McCrae & Costa, 2003).

The literature has validated the Big Five personality traits as predictors of performance in a variety of settings, including both organizational employment and isolated, confined, and extreme environments. For example, in a quantitative review summarizing the results of 15 meta-analytic studies investigating the relationship between the Five-Factor Model and job performance, all five personality traits predicted job performance in some way (Barrick et al., 2001). The Big Five personalities have also been researched in aviation, where pilots were found to possess similar personality profiles to astronauts (Fitzgibbons et al., 2004). Most NASA astronauts tend to have some level of piloting experience. This is not to suggest that every member of a future Mars mission will possess extensive piloting experience if any, but that it is an obvious advantage for selection.

In addition to organizational performance, the Big Five personalities have also been explored in isolated, confined, and extreme environments such as Antarctica. For example, in Antarctic analogs, up to 19% of the variance in individual performance was explained by the five personality factors (Palinkas et al., 2000), and neuroticism/emotional stability and agreeableness were found to be the strongest predictors of team performance within the current LDEM literature (Landon et al., 2017). Despite these assertions, it is important to highlight that some studies have yielded contrary results. For example, in a study in which personality data from 259 participants in NASA's final stage of astronaut applicants were collected between 1989 and 1995, results using an abbreviated version of the NEO Five-Factor Inventory (NEO-FFI) indicated that personality traits were not a predictor of applicant acceptance into the astronaut

corps (Musson et al., 2004). Plausible explanations for these findings included a lack of heterogeneity among the individuals tested and the possibility of some unidentified aspects of personality that were not assessed, but that may have played a role in the final selection (Musson et al., 2004). These conclusions highlight the multifaceted nature of astronaut selection as no single quality or attribute drives final crew selection, but rather many criteria must be met in order to make the final selection.

Nevertheless, there appears to be a consensus on the ideal personality profile for LDEMs. To best cope with the rigors of a LDEM, it is recommended that astronauts should possess above-average scores on conscientiousness and agreeableness, moderate levels of openness to experience, moderately low to moderately high levels of extraversion, and low levels of neuroticism (Suedfeld & Steel, 2000). According to Landon and colleagues, extremely high or low outliers for any personality factor would suggest unsuitability (Landon et al., 2017). The one exception to the rule would be extremely low levels of neuroticism, which would suggest very high emotional stability (Landon et al., 2017). Although the Big Five personality traits have been validated as one of the preferred models of astronaut selection, prior to this work, the unique role of personality in predicting an individual's stress response when experiencing communication delays in LDEM had not been investigated.

The purpose of this study was to examine the predictive effect of personality on stress levels when experiencing communication delays in a simulated space mission. Subjective stress levels were defined as "Difference in Stress" (DS) scores measured by calculating the difference between a pre- and post-stress Visual Analog Scale (VAS; Lesage et al., 2012). The delay was a 2-min one-way delay representing the early Mars transit phase. Individual differences were measured using the Big Five Inventory Scale-44 (BFI-44) (John et al., 1991; John et al., 2008), resulting in the Big Five personality traits: (a) extraversion, (b) agreeableness, (c) conscientiousness, (d) neuroticism, and (e) openness to experience. Locus of Control (LOC) was included in the analysis as an additional predictor and was defined by scores on Rotter's Internal/External Scale (Rotter, 1966). We hypothesized that the Big Five personality traits and LOC were significant predictors of stress during a 2-minute one-way communication delay in a simulated spaceflight mission.

Method

Population and Sample

The target population for this study was adult males and females in NASA's astronaut training program who may have been eligible for a future LDEM. The ideal accessible population consisted of members of NASA's astronaut candidate class; however, International Traffic in Arms Regulations and other restrictions made this unobtainable. For the purpose of this study, the accessible population was all healthy individuals affiliated with a private university in Florida as either students, faculty members, or staff, who possessed a bachelor's degree or were at minimum junior undergraduate level status. This accessible population was selected as a close approximation of individuals, similar to the ideal population because the members of NASA's astronaut training program must also be in good health and possess at least an undergraduate degree.

The sampling strategy for this study was convenience sampling. This study also may have inadvertently experienced snowball recruitment as participants who completed the study could have actively recruited colleagues, friends, and roommates. A demographic survey used for recruitment confirmed that the participants met the selection criteria, including the minimum educational requirements and the standards for self-reported astronaut-specific statements related to vision and healthy blood pressure. Finally, though they may not all presently represent the NASA astronaut candidate class, those meeting the selection criteria would meet the minimum requirements to eventually apply for NASA's astronaut training program. This was important in order to provide a more representative sample of the target population.

The demographic survey was made available online via *Qualtrics* and shared over email through the institution's online forum. Recruitment fliers were also put up strategically around the campus with contact information for those interested in participating in the study. The minimum sample size from the a priori power analysis for a sequential regression, with a medium effect size of 0.15 and six predictors, yielded 98 subjects for the study (Faul et al., 2009). A total of 198 individuals submitted responses to the online demographic survey for study participation eligibility. Of those 198 responses, 118 participants met the inclusion criteria, responded to a follow-up email for scheduling, and successfully completed the study. Eighteen responses were excluded for incomplete data, leaving a total of 100 participants with complete data on the dependent variable, the six predictor variables, and all the extraneous variables for further analysis. Participant age ranged from 19 to 51, with a mean of 23.32 and a standard deviation of 5.81. Also, 42 participants were male, whereas 58 were female. Finally, 31 of the participants reported having some level of piloting experience.

Apparatus

Stress Visual Analog Scale (VAS)

Stress VASs are commonly used in the medical field by occupational physicians to assess stress among workers (Dutheil et al., 2012; Dutheil et al., 2013; Lesage et al., 2012) and have been suggested as a tool for assessing perceived stress in both clinical and research settings (Lesage et al., 2012). This computerized assessment consisted of a single item (i.e., "What is your current stress level?") with a horizontal line divided into equally sized partitions on an 11-point scale (0 = No Stress to 10 = Agonizing) and a sliding locator. Participants were asked to mark the point that best represents their perception of their current stress state. This assessment was appropriate because it provided a quick, situational measure of perceived stress. VASs afford rapid administration and high completion rates, providing a useful advantage over more standard multi-item inventories that require more time and effort from the participant (Rossi & Pourtois, 2012). Furthermore, the use of a VAS over a more standard, multi-item inventory might have helped prevent any disruption to the flow of the experiment (MacLeod et al., 2012; Poma et al., 2005). The stress VAS was presented alongside other visual analog scales assessing dimensions including fatigue, level of difficulty, and communication quality. These supplemental scales were included to reduce participant awareness about the variables of interest. Experimental studies have found the stress VAS to possess good sensitivity for stress

events, and other work has shown the stress VAS to possess very satisfactory psychometric properties (Lesage et al., 2012).

BFI-44

The Big Five Inventory Scale-44 (John et al., 1991; John et al., 2008) is a 44-item measure with five scales: Extraversion (8 items), Agreeableness (9 items), Conscientiousness (9 items), Neuroticism (8 items), and Openness to experience (10 items). Participants are provided the phrase: "I am someone who…", followed by an item statement that participants rate in terms of agreement using a 5-point Likert scale ranging from 1 (*Disagree Strongly*) to 5 (*Agree Strongly*). The scale was developed as a time-efficient alternate measure of the Five-Factor Model that can be completed in approximately 10 min. The BFI-44 has been shown to possess a clear five-factor structure, reliability, convergent validity with other Big Five scales (such as the NEO-PI-R and NEO-FFI), and strong self-peer agreement (Benet-Martinez & John, 1998; John et al., 2008; Soto et al., 2008). The alpha reliability coefficients have been previously reported as .86 for extraversion, .79 for agreeableness, .82 for conscientiousness, .87 for neuroticism, and .83 for openness to experience, yielding an average of .83 (John et al., 2008). Based on the above findings, the BFI-44 was selected for measuring the Big Five personalities in this study for its robust psychometric properties and efficiency.

Rotter's Internal/External Scale

Rotter's Locus of Control Scale has been found to possess acceptable reliability and validity (Goodman & Waters, 1987; Rotter, 1966). This scale consisted of 29 forced-choice items where participants selected one of two options. Following Rotter's guidelines, scores were obtained by adding one point for specific items on the scale and then taking the sum of those scores. Among the 29 questions, items 1, 8, 14, 19, 24, and 27 were filler questions and excluded from data analysis, yielding scores ranging from 0 to 23. High scores reflected an external LOC, and low scores reflected an internal LOC.

Demographic Survey

A demographic survey was used to screen participants for eligibility with respect to educational status and to collect specific demographic information: participants' age, gender, and piloting experience. Participants were also asked to self-report their level of agreement with statements related to vision and blood pressure. The demographic survey was made available online via *Qualtrics*.

Simulation

The simulation was executed using the Re-entry Space Simulator by Wilhelmsen Studios (Wilhelmsen, 2018). This space flight simulation game was made specifically for personal computers and provided a realistic and interactive experience from the viewpoint of an astronaut. It is equipped with access to full historical missions, such as Project Mercury and the Apollo, and thanks to a custom mission editor, allowed the creation of new missions designed to challenge the user. All virtual cockpits were fully interactive, allowing the user to manually control almost

every single component of the cockpit, from gauging electrical systems to environmental control. For the purpose of this study, many of the elements from the Mercury capsule mission module were customized and developed to represent a Mars mission. The Mercury project contained some of the most basic controls and configurations ideal for this study. This was redesigned to make the participant feel fully immersed in a Mars mission, including modified backdrop graphics showing the red planet while completing tasks, system checks, and emergency protocols all characteristic of a real Mars mission. Prior to developing the customized mission, Re-entry was carefully inspected by multiple subject matter experts (SMEs) to ensure it possessed the necessary capabilities for carrying out simulated missions with communication delays as well as providing an adequate level of fidelity with respect to realism. Both concerns were met prior to developing the customized missions.

Study Design

This study used a correlational design to explore the predictive effect of the Big Five personalities on stress levels. There were two mission emergencies: primary life-support systems (PLSS) pressure regulator failure and carbon dioxide (CO_2) scrubber failure. These emergencies were evaluated by SMEs and deemed equivalent, and half of the participants were assigned to each. The basic structure of the 45-min mission was similar for each participant. Using re-entry, the mission incurred a 2-min one-way delay that would be expected during the initial stages of the transit phase (approximately 30 days into the mission). Participants were first briefed about the study and protocols. The briefing was read from a script and helped participants familiarize themselves with the setting, audio and communication equipment (i.e., walkie-talkie), and input controls for operating Re-entry (i.e., mouse and keyboard). Participants were also provided some tips on how to communicate efficiently with MCC during the simulation. Prior to starting, participants were required to complete a stress VAS to record baseline subjective stress scores. After completing the stress VAS, participants began the simulation, finding themselves inside the cockpit of a spacecraft, looking towards the darkness of space.

The simulation started with a 5–10-min tutorial involving artificial intelligence (AI), introducing and welcoming the participant to the mission. The AI then explained the controls and introduced the participant to the cockpit he or she would be operating in. Some of the controls included how to click buttons and switches, pull levers, and turn knobs. The AI also taught the participant how to monitor different panels, including pressure, carbon dioxide, temperature, oxygen, and battery levels. In addition to familiarizing participants with the controls, buttons, and the location of all the panels in the cockpit, the tutorial was also designed to reduce the chance of high-stress levels due to unfamiliarity when participants worked through the simulation.

After the tutorial was completed, the AI notified the participant that the 45-min mission would begin by clicking the prompt on the screen. The mission was divided into two segments, with the first 15 min dedicated to basic tasks, including monitoring systems, attitude control, and photography, and the latter 30 min for responding to one of two potential emergency scenarios programmed to occur at the 15-minute mark of the mission. The emergency scenarios were selected based on the results of Stuster and colleagues' Mars task analysis report (Stuster et al., 2019). They rated "*Respond to technical emergencies, following procedures and with equipment*

provided, during Cruise to Mars" (p .35) as the most important summary task statement. This summary statement was composed of 15 tasks. From those, three separate emergency scenarios were created: a) primary life-support systems (PLSS) pressure regulator failure, b) carbon dioxide (CO_2) scrubber failure, and c) lighting system power outage. Because this was part of a larger research project (Shirshekar, 2021) that investigated stress levels under delay versus no delay and thus required all participants completing two missions to compare the delay mission with a control, the selected emergency scenarios could not be functionally identical. However, they did need to be objectively similar, such that the number of steps, training and time required to complete each protocol were approximately equivalent. The scenarios also needed to be subjectively comparable by possessing similar levels of perceived risk, difficulty (complexity), and importance to the mission. This was essential to reduce any potential internal validity threats wherein differences in stress levels between the delay and control mission may have been due to slight discrepancies between the two emergency scenarios. Furthermore, by having multiple emergency scenarios, we ensured that any learning effects were minimized. The PLSS pressure regulator failure and CO_2 scrubber failure were rated as the most comparable of the three by SMEs and were selected and pilot-tested prior to this study. Finally, to satisfy the requirements of the larger research project (Shirshekar, 2021), all participants were counterbalanced based on scenario and delay. Thus, half the participants completed the delay scenario under the PLSS pressure regulator failure, while half the participants completed the delay scenario under the CO2 scrubber failure. This paper presents the findings for the delayed mission only.

The first 15 minutes were marked by several transmissions that were prerecorded and delivered by the researcher as MCC using a laptop and a speaker. The transmissions played through the speaker were relayed to the participant via the walkie-talkie to ensure consistency in the sound of transmissions from MCC. Some of the prerecorded transmissions were received by the participant at fixed times, while others were received based on their progress. The remainder of the transmissions were sent live from MCC and not prerecorded. Some of these transmissions were as short as a single word (i.e., roger). Several MCC generic responses to general questions from the participants in the pilot study were compiled and used in the study to minimize the variability of MCC transmissions. The transmissions were also contingent on what the participant was requesting or stating to MCC. For example, one participant might have required more assistance and thus more guidance from MCC, while others might have been more autonomous and less communicative. Thus, the number of transmissions, including both prerecorded and live from MCC and those sent by the participant, varied. In the first transmission, the participant was made aware of the mission pad on the table in front of them containing various checklists that needed to be completed.

Following the 45-min mission duration, the simulation was terminated, and participant post-mission stress levels were immediately collected via the stress VAS. Participants were then asked to complete the BFI-44 (John et al., 1991; John et al., 2008) and the Internal/External Scale (Rotter, 1966). To prevent participants from completing the mission with time to spare and to avoid having them simply wait idly for the 45-min clock to run out, the emergency scenarios were specially designed and tested to require a minimum of 30 min (beginning at the 15-min mark) to complete. As per SME input, this maintained the simulation time as a constant and avoided variable mission durations.

Participants were monitored via video feed by a researcher functioning as MCC in a nearby room. The simulation room was far enough from the researcher to ensure the participant could not hear the researcher, unless it was through their walkie-talkie. The simulation room was designed and configured based on some of the requirements for future LDEMs. One of the main design considerations was the size of the workspace. The researcher followed the guidelines and recommendations for the minimum acceptable Net habitable volume (NHV) for future LDEMs. NHV is defined as the minimum volume of a habitat that is necessary for mission success during LDEM missions with prolonged periods of isolation and confinement in a harsh/extreme environment (Whitmire et al., 2014). According to a consensus on minimum acceptable NHV, a minimum acceptable NHV of 25 m^3 (883 $ft.^3$) is recommended per person for future exploration missions with a maximum duration of 912 days. Furthermore, a workspace of 8.12 m^2 is recommended to allow up to four crewmembers to work simultaneously (Whitmire et al., 2014). The allowable workspace in the simulation room was designed based on these recommendations. Another design consideration was isolation, which includes physical isolation and acoustic isolation. Although it is not possible to re-create the physical isolation of future LDEMs, the participant and researcher were placed in separate rooms, and the simulation room was sound-proofed from outside noise distractions using a surround sound system that played continuous sounds of celestial white noise throughout the duration of the simulation. On the International Space Station, air circulation fans and other equipment produce a constant level of background white noise, making this a realistic soundscape. Finally, to re-create the lack of sensory stimulation and monotonous conditions, the windows were covered with two large projector screens. Prior to making these configurations, SMEs were consulted to ensure the proper level of fidelity was achieved. Of course, certain conditions such as microgravity and a true sense of isolation were not possible, thus threatening the ecological validity of the study. Within the simulation room, a chair and table were provided, along with the mission pad containing the checklists necessary for completing the mission.

Participants were assigned a number to ensure that the data remained anonymous following the completion of the study. Completion of the study was incentivized with a choice of space-related merchandise, such as socks, t-shirts, and other paraphernalia. The study was approved by the Institutional Review Board (IRB) of a private university in Florida, where the data were collected to ensure that attention was given to human subject research issues.

Results

The stress VAS was administered twice during the study, specifically at the beginning and end of the mission. The mean DS (post-test subtracted from the pretest) score was $M = 1.73$, with scores ranging from -3–7. The personality measures were collected after the mission was completed. All five of the Big Five personality traits were normally distributed, and the mean for LOC was $M = 11.24$, with scores ranging from 3–20. The descriptive statistics for the six continuous independent variables and the dependent variable (DS scores) are summarized in Table 1**.**

Table 1
Descriptive Statistics

	N	*M*	*SD*	Minimum	Maximum	Range
DS	100	1.73	2.04	-3	7	10
Extraversion	100	3.33	0.79	1.50	5.00	3.50
Agreeableness	100	3.92	0.59	2.33	5.00	2.67
Conscientiousness	100	3.74	0.63	2.00	5.00	3.00
Neuroticism	100	2.97	0.72	1.25	4.50	3.25
Openness	100	3.97	0.47	2.20	4.90	2.70
LOC	100	11.24	4.16	3	20	17

Note. These are descriptive statistics for the six predictor variables.
M = mean. SD = standard deviation. LOC = locus of control.

Inferential statistics consisted of a sequential multiple regression for DS scores. The predictor variables included extraversion, agreeableness, conscientiousness, neuroticism, openness to experience, and LOC. Multicollinearity was examined first. The variance inflation factors among the predictors were all less than 2. This demonstrated no multicollinearity. Regression assumptions were then examined to avoid biased regression coefficients and standard error estimates. The correction specification of the form of the relationship, reliable measurement of the independent variables, the constant variance of the residuals, independence of residuals, and normality of residuals assumptions were met. However, agreeableness, neuroticism, and openness to experience were removed from the inferential analysis to meet the correct specification of the independent variables.

The objective of this study was to examine the relationship between individual differences in personality and stress levels following a communication delay simulation. A sequential multiple regression was run, with extraversion and conscientiousness in the first model, followed by LOC entering next. The multiple regressions demonstrated a significant regression of extraversion and conscientiousness on DS scores, $F(2, 97) = 3.73$, $p = .03$, $R^2 = .07$, $RMSE = .20$. This indicated that extraversion and conscientiousness predicted 7% of the variance in DS scores. Examining the individual factors in this model, significant relationships were found with extraversion, $t(97) = -2.12$, $p = .04$, $sr^2 = .04$ with $B = -.55$, $\beta = -.22$, $SE = .26$; and conscientiousness, $t(97) = 2.24$, $p = .03$, $sr^2 = .05$ with $B = .74$, $\beta = .23$, $SE = .33$. Interpreting the corresponding regression coefficients, $B_E = -0.55$ and $B_C = 0.74$, these results indicate that by holding all other variables constant, a participant's DS score is predicted to drop approximately 0.55 points on average for every one-point increase in extraversion score in the presence of conscientiousness, and a participant's DS score is predicted to increase by 0.74 points on average for every one-point increase in conscientiousness score in the presence of extraversion.

When LOC entered into the model, the regression was significant, $F(3, 96) = 5.74$, $p < .01$, $R^2 = .15$, $RMSE = .19$. This showed that extraversion, conscientiousness, and LOC predicted 15% of the variance in DS scores. The increase caused by LOC entering the model was also significant, $\Delta F(1, 96) = 9.13$, $p < .01$, $\Delta R^2 = .08$. This indicated that LOC predicted an additional 8% of the variance in DS scores. The parameters are summarized in Table 2. This demonstrated that by holding all other variables constant, a participant's DS score is predicted to drop

approximately 0.39 points on average for every one-point increase in extraversion score in the presence of conscientiousness and LOC, and a participant's DS score is predicted to increase by 0.96 points on average for every one-point increase in conscientiousness score in the presence of extraversion and LOC. Also, for every 1-point increase in LOC, the DS score is predicted to increase by .15 points on average in the presence of extraversion and conscientiousness.

Table 2
Sequential Multiple Regression Model Summary.

	B	***SE***	***CI***	**β**	***t***	***p***	***pr2***	***sr2***
(Constant)	-2.21	1.61	[-5.40, 0.98]		-1.37	0.17		
E	-0.39	0.26	[-0.90, 0.12]	-0.15	-1.53	0.13	0.02	0.02
C	0.96	0.33	[0.31, 1.60]	0.29	2.94	0.00	0.08	0.08
LOC	0.15	0.05	[0.05, 0.25]	0.30	3.02	0.00	0.09	0.08

Note. These are inferential statistics for the final regression model with extroversion (E), conscientiousness (C), and locus of control (LOC). *B* = coefficient. *SE* = standard error. *CI* = confidence interval. β represents the standardized regression coefficient of each variable. sr^2 and pr^2 were partial and semi-partial correlation coefficients, which indicated the portion of the variance explained solely by the variable in the presence of other variables and the one by removing the effect of other variables.

Discussion

The findings indicated that two of the Big Five personality traits, extraversion and conscientiousness, were significant predictors of DS scores when incurring a 2-min one-way delay with MCC. Together, extraversion and conscientiousness predicted about 7% of the variance in DS scores. LOC was also a significant predictor of DS scores, predicting another 8% of the variance. These results may collectively imply that conscientiousness, extraversion, and LOC could be important personality traits for future LDEM crew selection. For example, increased levels of conscientiousness among crewmembers may lead to increased awareness of communication delays during LDEMs, thus resulting in higher stress levels. Similarly, higher LOC scores are indicative of a more external disposition. Thus, crewmembers with more external LOC scores could be more reliant on outside help (i.e., MCC), which could be challenging with the implemented delay. Although increased levels of extraversion correlated with lower stress levels, it could be theorized that crewmembers with excessively high levels of extraversion, who would likely be in more need of conversation and social interaction, could be prone to feeling increased stress and frustration from the limited communication with MCC. Thus, some degree of introversion may be desirable (Landon et al., 2017). On the other hand, given that only two of the Big Five personality traits were significant predictors, these findings may also collectively imply that the Five-Factor Model may not be a major predictor of individual well-being when incurring a communication delay with MCC, and that other personality models or traits, such as LOC, may merit further investigation. This would support the current multifaceted practice of NASA astronaut selection, in which no single factor drives

selection. This implication is also timely with the rise of private companies and space tourism, where everyday individuals possessing unique personality profiles may be selected for future space missions.

One recommendation for practice is for NASA and private spaceflight companies to place further emphasis on Big Five traits, such as conscientiousness and extraversion as well as other personality traits such as LOC. However, because of the lack of astronaut performance data to date, it is difficult to draw firm conclusions for astronaut selection recommendations. It is recommended that future researchers replicate the study but increase the length of both the communication delay and the simulation. Previous literature exploring communication delays in behavior and performance suggest at least 1 hour is necessary to ensure enough time to capture behavioral assessments and complete ratings (Palinkas et al., 2017). Another recommendation is that researchers study individual well-being and performance in tandem, as much of the literature exploring the predictive effect of the Big Five in isolated, confined, and extreme conditions are predominantly performance-based. It is possible individual well-being and performance may be associated with one another or that performance could mediate the relationship between delay and individual well-being. This study was limited in its capacity to implement multiple stress assessment tools due to the COVID-19 Pandemic. It is recommended that future studies implement multiple stress measures to capture a more comprehensive evaluation of stress. This could include both subjective and physiological assessments. Because stress is a multidimensional construct, assessing multiple physiological markers (blood pressure, heart rate, galvanic skin response, and salivary markers) may be more useful for documenting effects. Furthermore, previous studies investigating VAS data have found them to lie somewhere in between ordinal and interval scales (McCormack et al., 1988; Philip, 1990; Price et al., 1994). However, with scores generally ranging from 0 to 100 (or 0 to 10), they are said to have equality between intervals and can thus be subjected to parametric statistics (Kersten et al., 2014). Following these assertions, it was decided that the DS scores would be considered interval scale for this study, but it must be cautioned that the literature remains somewhat ambiguous as to where VAS data truly lie.

This was the first study to explore the relationship between personality and stress during communication delays; to build on this work and prepare for potential missions, future communication delay studies should investigate stress measures and personality from a team perspective. Finally, it is recommended that future researchers incorporate more predictor variables to reflect the holistic multi-trait, multi-method approach, as no single factor drives astronaut selection.

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