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Isolation and confinement due to the COVID-19 pandemic: Lessons for human spaceflight

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ABSTRACT

Background: Astronauts live and work in isolated, confined, extreme (ICE) environments that create both high stress and the need for high performance. The COVID-19 pandemic created ICE-like conditions across the globe by confining people to their homes under the ever-present threat of disease. Our goal is to understand the impact of prior experience in ICE on coping, using the pandemic as a pseudo space analog environment.

Methods: We administered a survey three times with 7 days between administrations. A total of 82 participants completed all three survey sessions, and these participants were divided into three groups for analysis. The first group is those with prior experience in an ICE environment (n = 17; 7F/10 M), the second is those aged 30–55 with a master’s or doctoral degree and without prior experience (n = 22; 10F/12 M), and the third is the general population (n = 43; 27F/16 M). Linear mixed models were used for statistical analysis of the results, given the unequal sample sizes.

Results: The experienced group did not show healthier mental health scores than the astronaut-like group, but both groups displayed higher scores than the general population. However, work productivity scores for the experienced group were higher on average than the other two groups.

Discussion: Results suggest that prior experience in ICE may improve the capability to maintain productivity—corresponding to the idea of resilience. However, experience may not improve mental health maintenance, suggesting that other approaches are needed to prepare astronauts for the mental health stressors of long-duration exploration missions.

1. Introduction

Astronauts are a population of workers that live and operate in isolated, confined, extreme (ICE) environments as part of their job description. They are confined to a spacecraft, have access to limited resources, only interact in person with their fellow crew members for missions spanning weeks to months, are away from family members and loved ones, and are surrounded by the extremely dangerous space environment that poses a perpetual threat to their well-being. Astronauts on long-duration exploration missions may be spending years in this type of ICE environment, making them increasingly likely to experience psychological stress that can impact mission success [26, 46]. Similar conditions are experienced on Earth by groups that live and work in ICE environments; members of the military on deployment, submariners, wilderness explorers, and emergency medical technicians all experience similar isolation from family and friends, confinement to their operational area, and extremely dangerous situations they must navigate. The psychological stress due to operating in an ICE environment compounds the impacts of cognitive load, emotional stress, conflict between crewmembers, and sleep quality [3, 32, 35, 36]. These issues have been observed in space analog studies (controlled space-like facilities that house crews for extended periods), and they impact crews’ safety, productivity, health, and happiness while risking mission success [2, 3, 12, 42]. Behavioral health and performance issues have been stated as one of the highest risk factors for future crewed missions because of the unknown effects of extended periods (>1 year) in ICE environments and will only become more severe as mission durations increase in our return to the moon and journey to Mars.

Many studies aimed at better understanding the effects of ICE environments have been conducted in Earth-based space exploration analogues that create ICE environments for crews of 4–12 over varying time lengths. Some of these include the Mars500 study [3, 42], winter-over...
studies in Antarctica [12], the Hawai’i Space Exploration Analog and Simulation (HI-SEAS) Mars analog facility [2], and the Human Exploration and Research Analog (HERA) at NASA’s Johnson Space Center [33]. Some studies conducted within these analog environments have shown the development of symptoms of depression, increased stress, and anxiety, which indicates that psychological health poses a real threat to the success of future missions, despite the selection of crews without a history of psychological health problems [35].

Skills in emotional independence, performance under stress, teamwork, motivation and self-direction, and group living are highly sought-after in astronaut candidates and in those participating in space analog studies, because it is believed that these qualities will make crews more capable of coping with austere conditions [16,20]. Those with previous experience in ICE environments are often favored during astronaut selection, but the benefit of previous experience on future functioning in ICE environments is unknown. Further, studies have not been able to compare these high-performing individuals to the general population since selection for participation even in a low-fidelity analog is already highly competitive with thorough vetting processes.

The COVID-19 pandemic has created an opportunity to study a large sample (as compared to analogues with groups of ~4–12) of individuals living in ICE-like conditions. During the time of this study, non-essential workers were required at varying levels to work from home and stay in their homes as much as possible to prevent the rampant spread of disease. We saw this as an opportunity to investigate the impacts of prior experience by recruiting individuals with work experiences as astronauts, medical professionals, military members, wilderness explorers, and submariners and comparing them to the general public. We also targeted recruitment toward a group of astronaut-like participants without prior experience and saw this as an opportunity to study their response to this ICE-like environment in comparison with the general public to inform future studies. We used a longitudinal, survey-based study to assess lifestyle and self-assessments of mental state to answer these fundamental questions. We hypothesized that a) individuals with prior experience in ICE environments (as assessed by a survey question) would have healthier scores in self-assessments of mental health and would maintain more stable scores over each session than both the astronaut-like and general population group, and b) Individuals with ICE experience would have better work productivity and positivity scores than both the astronaut-like and general population groups.

2. Methods

2.1. Survey instrument

The survey was administered three times, 7 days apart between April 20 and June 1, 2020. Some sections of the survey were removed after the first session because their measurement scope was a 1-month period instead of a 7-day period. Participants took the survey through Qualtrics (a web-based survey platform) from their own homes. All survey responses were anonymized.

The survey includes four separate sections: 1) introductory questions, 2) level of isolation and confinement (Level of IC), 3) lifestyle, and 4) self-assessments of psychological state.

Introductory questions: These questions gathered information on age, sex, gender, height, weight, race, ethnicity, religion, nonspecific preexisting medical conditions (including mental illness), and education level. Education level was inclusive of degrees currently sought by participants. Guidance for the sex and gender questions’ wording and response options for this section was derived from [19]. Additionally, participants were asked to provide their home address to identify groups of participants living together and state/country of residence. Specific address information was not stored.

Level of IC: The purpose of the Level of IC survey was to assess the similarity between each participant’s living conditions and a truly isolated and confined environment. This section of the survey was developed by the authors and has not yet been formally validated. The questions in this section covered whether or not a shelter-in-place, stay at home, or lock-down order had been instated by the government, how long these conditions had been in place, and how many times participants had left the house to take care of someone, work, or for non-essential reasons. This section was repeated during each session to acquire Level of IC data for the previous 7 days.

Lifestyle: The Lifestyle section of the survey included 7 sections covering the aspects of life most analogous to spaceflight: 1) sleep quality, 2) exercise, 3) eating behavior, 4) work performance, 5) recreation, 6) social interaction, and 7) threat assessment. The sleep quality section was derived from the Pittsburgh Sleep Quality Index (PSQI) with the free response and partner-dependent questions removed [11]. Within the work productivity section, each participant was asked if they were ever employed in one of the following job categories: military, medical professional, astronaut, submariner, or wilderness explorer (the selection of multiple professions was allowed). Each of these job types is associated with some level of ICE. Those who selected any of those options are considered ICE-experienced/trained because of the nature of each of these professions and the level of ambient stress associated with them. Work productivity was measured with a subset of four questions within the “work productivity” section of the survey assessing levels of boredom, focus, and performance over the last 7 days.

Self-assessments of psychological state: These included both single-session metrics and longitudinal metrics described herein.

Single-session metrics: The Brief Coping Orientation to Problems Experienced (Brief COPE) is a standard measure of coping strategies for individuals experiencing challenging life events. The original survey assesses 14 different coping strategies with 28 question items [13]. These 14 different strategies were reduced to four in a cross-sectional study by [4], so we have used these four strategies to analyze our survey responses: social support (8 items), problem solving (4 items), avoidance (10 items), and positive thinking (6 items). The Perceived Stress Scale (PSS) is a widely used 10-item survey instrument for assessing the respondent’s perception of stress in their life. The question items focus on how “unpredictable, uncontrollable, and overloaded respondents find their lives” [15]. This survey has been validated for assessing stress levels over the previous month, so these questions were only asked during the first session.

2.2. Longitudinal metrics

The Depression, Anxiety, and Stress Scales (DASS) is a 42-item questionnaire assessing perceived levels of each factor over the preceding week [28]. It has been used widely for studies of both clinical and non-clinical participant populations in a variety of experimental structures, exhibiting strong internal consistency across applications in both the full 42-item form and 21-item validated short-form [8,34,39]. We implemented the 42-item version for this study. We also included the revised Profile of Mood States (POMS) as a measure of affect with 22 items and 4 subscales: vigor, irritability, fatigue, and numbness [31]. This shortened version was used to reduce survey fatigue and limit redundancy. One of the descriptive words in the shortened version (“chippy”) was eliminated to limit participant confusion about its meaning.

Threat assessment was measured as an aggregate score of three questions about how dangerous respondents feel that COVID-19 is, how personally threatened they feel, and how worried they are for the health of their family and friends. We included the “Personal Strength” subscale from the Positive Effects of Being in Space (PEBS) questionnaire to assess the impact of this period of isolation on participants’ perceptions of their own emotional autonomy—this is referred to herein as a “positivity” score [24,40]. This subscale comes from the Posttraumatic Growth Inventory (PTGI), which is used often for monitoring treatment efficacy for posttraumatic stress disorder (PTSD) [43]. Other subscales within the PEBS questionnaire were not included to keep the survey short and
to eliminate spaceflight-specific items. The four questions are listed in Table 1.

2.3. Participants

Participants were recruited through email and social media, and the only requirement to participate was an age of 18+. There were no exclusion criteria, but only data from participants who completed all three survey sessions are included here. Participants with prior experience in ICE and astronaut-like attributes were targeted, and the advertisement was broadly disseminated. Before completing the survey, all participants read and signed informed consent approved by the University of Colorado Boulder Institutional Review Board. A total of 82 participants completed all three survey sessions, and only the data from this group will be discussed here.

For this investigation, the group of 82 participants was split into three sub-groups: 1) ICE-experienced or trained (ICEET; n = 17; 7F/10 M), 2) astronaut-like (AL; n = 22; 10F/12 M), and 3) general population (GP; n = 43; 27F/16 M). The ICEET group was formed based on answers to the aforementioned question about previous employment as military, medical professional, astronaut, submariner, or wilderness explorer. All of these professions require training in high-stress environments and some degree of isolation and confinement, so we consider this group ICE-experienced. The AL group was formed from those without prior experience in ICE environments, ages 30–55, and a Masters or Doctorate education level. We did not differentiate between participants with degrees in Science, Technology, Engineering, and Math (STEM) and those with degrees in non-STEM disciplines, but we purposefully recruited individuals in STEM to best match the NASA astronaut requirements [17]. The GP group consists of the remaining participants, outside of the requirements for the other two groups. Participants who met the requirements for the ICEET and AL groups were included only in the ICEET group with the intention of isolating prior experience and/or training in ICE as an independent variable. It is worth noting that all three groups are majority white. While racial minority groups are underrepresented, the three groups do match each other well in terms of racial distribution, so we can draw conclusions about the comparison between the three groups, but cannot claim to understand trends within groups.

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2.4. Statistical analysis

The available data from this study is vast, so the first step in statistical analysis was to down-select items of interest through data visualization. We visualized the comparison between the GP, AL, and ICEET groups and their evolution over the three survey sessions. For the two sections of the survey only administered during the first session (Brief COPE, and PSS), we conducted a Kruskal-Wallis nonparametric analysis of variance to test whether there were differences in the scores between groups.

For threat assessment and sleep, only descriptive statistics were used to look for large differences between groups that could be identified as confounding factors for the results. For the sections of the survey that were repeated during each session for all three groups, we implemented linear mixed effects models to explore variations between groups and sessions. We did not implement a repeated measures analysis of variance (RMANOVA), because the response variables were not normally distributed, even after transformation. The mixed effects model is robust to non-normality. In the mixed effects model, the fixed effects are the group and session, and the random effect is the participant number (included to account for inter-individual variability).

A separate model was used for each response variable, where the response variables are the scores on each of the self-assessments of psychological state. The mixed effects models used a restricted maximum likelihood to perform estimates instead of the log-likelihood alternative to better handle the unequal sample sizes between groups. The mixed effects model provides estimates for the fixed effects and a t-statistic computed using Satterthwaite’s method with a corresponding p-value indicating the impact of each on the estimates. P-values less than α = 0.05 led us to explore the differences between groups further using a post-hoc Tukey Multiple Comparison test. We chose to use the Tukey method because it is conservative when unequal sample sizes are being compared to each other [22]. For results from those comparisons again returning a p-value less than α = 0.05, we calculated the Hedge’s g effect size. Hedge’s g was chosen because it out-performs the more common Cohen’s d for sample sizes less than 20, which we have for one of the three groups [23].

3. Results

3.1. Threat assessment

To better understand the “extreme” part of this ICE environment, we examined each group’s responses to the “threat assessment” portion of the survey to assess each group’s perception of the COVID-19 pandemic. We saw negligible differences in threat assessment both between groups and between sessions; the range in means for all groups from all sessions was 4.59–5.91, and the range in standard deviations was 1.7–2.0. This indicates that the three groups were equally impacted by the extreme element of the ICE environment, and self-assessments of psychological health were not impacted by varied perceptions.

3.2. Sleep

Because of the strong correlation between sleep and mental health, we inspected participants’ responses to sleep quality and duration questions to look for obvious differences between the three groups. There were no significant differences between the response distributions to these two questions between the three groups. These responses indicate that sleep has not been greatly impacted by the pandemic with most participants responding that their sleep is “fairly good” and that the majority get 7–9 h per night.

Table 1

| Questions | Scoring |
|-----------|---------|
| Positivity | I am better able to accept the way things work out. not at all: 3 | not at all: 3
| | I know better that I can handle difficulties. moderately so: 2 | somewhat: 2
| | I have a greater feeling of self-reliance. very much so: 0 | very much so: 0
| | I discovered that I’m stronger than I thought I was. not well at all: 0 | not well at all: 0
| Work productivity | How well have you performed your work responsibilities in the last 7 days? somewhat well: 1 | somewhat well: 1
| | How bored have you been during work time over the last 7 days? moderately well: 2 | moderately well: 2
| | Have you had trouble focusing while working over the last 7 days? very well: 3 | very well: 3
| | Are your work performance, focus, and level of boredom different than they were before this period of isolation? not at all: 3 | not at all: 3
| | | somewhat: 2 | somewhat: 2
| | | moderately so: 1 | moderately so: 1
| | | very much so: 0 | very much so: 0
3.3. Brief COPE and PSS

The Kruskal-Wallis test of the four different factors in the Brief COPE survey returned a result indicating a statistically significant difference between groups for only one factor: avoidance (H = 6.24, p = .04). Levels of avoidance were higher on average in the GP group than in the other two groups. There was not a statistically significant difference between PSS scores between the three groups (H = 5.06, p = .08). This indicates that the three groups started out with comparable levels of perceived stress and gives strength to our analysis of stress conducted within the DASS each week.

3.4. DASS and POMS

Descriptive statistics for each response variable and the results of the linear mixed model for each are shown in Table 1. Table 2 shows the results of the post-hoc Tukey comparisons and Hedge’s g effect sizes. For depression, the GP group was a significant fixed factor in the mixed model. The subsequent Tukey comparison did not return a significant difference between the possible combinations of all three groups; however, the descriptive statistics show that the mean depression score for the GP group was higher than the AL and ICEET groups during all three sessions, and the GP group showed a mean decrease of 2.41 from session 1 to 3. The session 1 and session 3 fixed factors also had significant impact on the depression model, and the subsequent Tukey comparison revealed a significant difference between sessions 1 and 3. The effect size between the GP group and session was large, while the effect sizes between the AL and ICEET groups and session, respectively, were medium. All three groups and the session 1 and 2 fixed effects were significant for anxiety. The Tukey comparison between groups revealed a significant difference between the GP and ICEET groups and a medium effect size. Between sessions, the Tukey comparison revealed a significant difference between sessions 1 and 3 with the ICEET group exhibiting a large effect size over the three sessions. This large effect size is negative, showing the overall decrease in anxiety scores for the ICEET group over the three sessions.

The GP group and all three sessions were significant factors for stress. Tukey comparisons did not reveal a significant difference between groups but did show a significant difference between sessions 1 and 3. All three groups showed a large effect size when compared internally between sessions. Given these statistically significant findings, it is also informative to look at the progression of each group with respect to the five different levels of symptom severity. Fig. 1 shows the percentage of each group falling under the normal threshold for depression, anxiety, and stress. The percentage of the GP group in the normal category starts lowest but increases over the three sessions for all three metrics. The AL

| Depresssion | session 1 | session 2 | session 3 | Δ 1-3 | LMM statistics |
|------------|-----------|-----------|-----------|------|----------------|
| GP         | 8.80 ± 7.4| 6.97 ± 6.9| 6.39 ± 6.3| -2.41| 7.44; p < .001 |
| AL         | 4.43 ± 5.2| 4.46 ± 5.0| 3.91 ± 5.4| -0.52| -1.80; p = .08  |
| ICEET      | 5.36 ± 8.9| 5.13 ± 10.4| 5.13 ± 9.7| -0.23| -0.93; p = .35  |
| LMM statistics | 7.44; p < .001 | -1.72; p = .09 | -2.43; p = .02 |
| Anxiety    |           |           |           |      |                |
| GP         | 5.43 ± 7.7| 4.46 ± 6.6| 3.25 ± 6.0| -2.18| 6.33; p < .001 |
| AL         | 1.90 ± 1.9| 1.27 ± 1.7| 1.36 ± 2.1| +0.54| -2.19; p = .03  |
| ICEET      | 0.79 ± 1.9| 0.80 ± 1.3| 0.93 ± 2.3| +0.14| -2.48; p = .02  |
| LMM statistics | 6.33; p < .001 | -1.68; p = .09 | -2.74; p = .01 |
| Stress     |           |           |           |      |                |
| GP         | 11.10 ± 10.3| 9.43 ± 10.9| 7.83 ± 10.2| -3.27| 8.52; p < .001 |
| AL         | 7.62 ± 5.1| 5.50 ± 3.9| 5.82 ± 5.9| -1.80| -1.49; p = .14  |
| ICEET      | 5.50 ± 6.0| 5.40 ± 6.3| 4.80 ± 6.1| -0.70| -1.53; p = .13  |
| LMM statistics | 8.52; p < .001 | -2.30; p = .02 | -3.17; p = .002 |
| Vigor      |           |           |           |      |                |
| GP         | 7.80 ± 1.7| 9.37 ± 4.0| 9.50 ± 4.1| +1.70| 16.2; p < .001 |
| AL         | 7.48 ± 1.5| 7.50 ± 4.5| 8.36 ± 5.3| +0.98| -1.10; p = .28  |
| ICEET      | 8.21 ± 1.8| 6.47 ± 4.4| 7.40 ± 4.8| -0.81| -1.39; p = .17  |
| LMM statistics | 16.2; p < .001 | 0.75; p = .45 | 1.58; p = .12 |
| Irritability |        |           |           |      |                |
| GP         | 2.49 ± 2.6| 3.20 ± 4.2| 2.28 ± 2.9| -0.21| 5.85; p < .001 |
| AL         | 3.00 ± 3.0| 2.04 ± 2.8| 2.73 ± 4.5| -0.27| -0.52; p = .75  |
| ICEET      | 1.79 ± 2.6| 1.80 ± 2.7| 2.00 ± 2.3| +0.21| -1.07; p = .29  |
| LMM statistics | 5.85; p < .001 | 0.39; p = .70 | 0.13; p = .90 |
| Fatigue    |           |           |           |      |                |
| GP         | 5.86 ± 4.2| 5.57 ± 4.4| 5.36 ± 3.5| -0.50| 10.0; p < .001 |
| AL         | 3.76 ± 2.8| 3.73 ± 3.0| 4.14 ± 3.8| +0.38| -1.85; p = .07  |
| ICEET      | 3.29 ± 3.7| 3.33 ± 2.9| 3.60 ± 5.1| +0.31| -2.09; p = .04  |
| LMM statistics | 10.0; p < .001 | -0.58; p = .56 | -0.82; p = .41 |
| Numbness   |           |           |           |      |                |
| GP         | 1.49 ± 1.8| 1.63 ± 1.7| 1.39 ± 1.5| -0.10| 8.17; p < .001 |
| AL         | 0.81 ± 1.0| 0.77 ± 0.8| 0.68 ± 0.9| -0.13| -2.69; p = .01  |
| ICEET      | 0.71 ± 0.9| 0.60 ± 0.7| 0.93 ± 1.6| +0.22| -2.20; p = .03  |
| LMM statistics | 8.17; p < .001 | 0.09; p = .93 | -0.60; p = .55 |
| Positivity |           |           |           |      |                |
| GP         | 6.72 ± 3.0| 6.14 ± 3.1| 6.19 ± 3.6| -0.53| 10.7; p < .001 |
| AL         | 6.59 ± 2.9| 6.14 ± 2.8| 5.91 ± 4.0| +0.68| 0.26; p = .79  |
| ICEET      | 9.12 ± 3.0| 3.82 ± 3.4| 3.59 ± 3.5| +5.53| 1.48; p = .14  |
| LMM statistics | 10.7; p < .001 | 2.85; p = .01 | 3.01; p = .003 |
| work productivity |   |           |           |      |                |
| GP         | 2.71 ± 2.3| 2.63 ± 2.9| 2.83 ± 2.5| +0.12| 16.4; p < .001 |
| AL         | 3.43 ± 2.1| 3.77 ± 1.9| 3.46 ± 2.3| +0.03| 1.5; p = .15  |
| ICEET      | 4.00 ± 3.0| 4.27 ± 2.6| 4.67 ± 2.3| +0.67| 2.4; p < .02  |
| 6.4; p < .001 | 0.52; p = .66 | 1.16; p = .25 |
and ICEET groups do not show the same trend of improvement and are similar to each other and higher than the GP group during all three sessions.

The four metrics within the POMS are vigor, irritability, fatigue, and numbness. Descriptive statistics and results of the linear mixed models for the POMS metrics are shown in Table 2, and the post-hoc test results for numbness are shown in Table 3. The GP and ICEET groups were significant factors for fatigue, and descriptive statistics show that scores for the two groups were lower on average than the GP group. The results for numbness show a similar pattern.

All three sessions and the GP group were significant factors for positivity. All three groups show a decrease over the three sessions, the ICEET group shows a decrease in mean positivity of 5.53 points between sessions 1 and 3 (most of the decrease occurred between sessions 1 and 2). This group had the highest score during session 1 and had the lowest score in session 3.

In the mixed model with work productivity as the response variable, the GP and ICEET groups were significant factors for work productivity, and Tukey contrasts revealed a significant difference between the two with a medium effect size. As shown in the descriptive statistics in Table 1 and in Fig. 2, all members of the ICEET group except 3 increased in work productivity from session 1 to 3, showing a bulk increase not seen in the other two groups.

### 4. Discussion

The results of this study reveal an interesting pattern that is corroborated by the literature: training and experience do not seem to affect self-assessments of mental health, but they do affect work productivity, which corresponds to resilience. Resilience has been defined in many ways, among them positive adaptation to adversity and the ability to continue functioning normally despite adversity [5,29]. The second definition leads us to draw the connection between work productivity and resilience, but further investigation is required to understand the relationship between work productivity and resilience in this context. This conclusion is drawn from the fact that the self-assessments of mental health (DASS and POMS) did not differ greatly between the AL and ICEET groups, but the work productivity metric did.

DASS and POMS scores do not appear to be affected by prior experience or training. The AL and ICEET groups scored similarly on both surveys, and both scored higher on average than the GP group in all areas. We hypothesized that the ICEET group would score better than the GP group, but we did not anticipate the similarity of scoring between the AL and ICEET groups, but the work productivity metric did.

The plots show the percentage of the GP, AL, and ICEET groups (from left to right) scoring within the “normal” threshold for depression, anxiety, and stress over the three sessions. The dotted lines are session 1, dashed are session 2, and solid are session 3. Scores for the GP group are lower than the AL and ICEET groups, but the GP group shows improvement between sessions that the other two groups do not.
Table 3
Results from post-hoc comparisons between groups and sessions and Hedge’s g effect size for each comparison for depression, anxiety, stress, numbness, positivity, and work productivity.

|                  | Tukey contrast between groups | Effect size (Hedge’s g) | Tukey contrast between sessions | Effect size (Hedge’s g) |
|------------------|-------------------------------|-------------------------|--------------------------------|-------------------------|
| Depression       |                               |                         |                                |                         |
| GP –             | z = –1.80; p = .001           | 1.00                    | –1.72; p = .20                 |                         |
| AL –             | z = –1.17; p = .071           | –.20                    |                                |                         |
| GP –             | z = .25;                     | 2.3                     | –.72; p = .75                 |                         |
| ICEET            | z = –.62; p = .020           |                         | –.75                           |                         |
| AL –             | Z = .60; p = .38             |                         | –.20                           |                         |
| ICEET            | –                             |                         | –.20                           |                         |
| Anxiety          |                               |                         |                                |                         |
| GP –             | z = –2.19; p = .001          | .48                     | –1.68; p = .12                 |                         |
| AL –             | –                              |                         |                                |                         |
| GP –             | z = .57;                     | 2.3                     | –1.06; p = .21                 |                         |
| ICEET            | –                              |                         | –.54                           |                         |
| AL –             | z = .35; p = .05             |                         | –.37                           |                         |
| ICEET            | –                              |                         | –.02                           |                         |
| Stress           |                               |                         |                                |                         |
| GP –             | z = –1.49; p = .001          | .34                     | –2.30; p = .06                 |                         |
| AL –             | –                              |                         |                                |                         |
| GP –             | z = .36;                     | 2.3                     | –.87; p = .01                 |                         |
| ICEET            | –                              |                         | –.66                           |                         |
| AL –             | z = .06; p = .54             |                         | –.17                           |                         |
| ICEET            | –                              |                         | –.01                           |                         |
| Numbness         |                               |                         |                                |                         |
| GP –             | z = –2.69; p = .001          | .57                     | –0.99; p = .86                 |                         |
| AL –             | –                              |                         |                                |                         |
| GP –             | z = .49;                     | 2.3                     | –.68; p = .82                 |                         |
| ICEET            | –                              |                         | –.82                           |                         |
| AL –             | z = .23; p = .49             |                         | –.68; p = .77                 |                         |
| ICEET            | –                              |                         | –.77                           |                         |
| Positivity       |                               |                         |                                |                         |
| GP –             | z = 0.26; p = .04            | –.04                    | 2.85                           |                         |
| AL –             | –                              |                         |                                |                         |
| GP –             | z = 1.48;                   | 2.3                     | –0.16; p = .59                |                         |
| ICEET            | p = .30                     | -                        |                                |                         |
| AL –             | z = 1.10;                   | 1.9                     | –3.01; p = .01                |                         |
| ICEET            | p = .51                     |                          |                                |                         |
| Work productivity|                               |                         |                                |                         |
| GP –             | z = 1.45;                   | 1.2                     | 0.52; p = .86                 |                         |
| AL –             | p = .31                     |                          |                                |                         |
| GP –             | z = 2.42;                   | 2.3                     | –1.16; p = .48                |                         |
| ICEET            | p = .04                     |                          |                                |                         |
| AL –             | z = 1.05;                   | 1.3                     | –2.07; p = .06                |                         |
| ICEET            | p = .54                     |                          |                                |                         |

* Small effect size.
* Medium effect size.
* Large effect size.

Group scores in the ICEET group increased over the three sessions (shown in Fig. 2). This improvement could be an indication that the ICEET group was able to adapt to the situation and find new ways to be productive. This shows resilience in this group that is not mirrored in either the AL or GP group. Resilience is known to be a trainable quality and there is a wide breadth of ongoing research for training resilience in groups working in demanding jobs [9,25]. The U.S. Army has implemented a Master Resiliency Trainer (MRT) course toward this goal [14,38]. In this context, enhanced resilience is seen as a method of protecting soldiers’ psychological health, but our results suggest that within our participant group, resilience and psychological health may be separate to some degree; members of the ICEET group were able to maintain work productivity – displaying resilience – while still experiencing the impact of stressors on their psychological health. While this could raise the alarm for future long-duration exploration missions, meaningful work has been shown to help people maintain psychological health, so a feasible countermeasure for maintaining psychological health is ensuring that crews on a Mars mission have meaningful tasks to complete during transit [6].

In each result discussed thus far, the ICEET group scored higher than the GP group. Surprisingly, this was not the case for positivity. The ICEET group did have the highest mean positivity during session one but dropped drastically to have the lowest mean positivity during session 3. This could be due to the lack of novelty experienced by the participants in this study. Ihle et al., 2006 state that space travel can be stressful in both exhilarating and distressing ways. The ICE environment caused by the COVID-19 pandemic is certainly distressing, but participants were for the most part in their own homes, lacking new experiences. This lack of exhilarating experience could explain the lack of salutogenesis shown in all three groups. In some crewed space missions, the exhilarating experience of spaceflight seems to outweigh the potential negatives of living and working in an ICE environment, but this has been shown to change as mission durations increase [44]. Monotony and lack of stimulation are key concerns for long-duration missions, especially those without a constant view of the Earth. Thus, the dynamic changes in positivity in the ICEET group should encourage the continual assessment of positivity among crew members in analog missions and true spaceflight to better understand and mitigate this potential risk.

A potential limitation of this study is in the lack of baseline measurements of participants’ state pre-pandemic. Specifically, it is possible that the assessment of positivity would be more accurate once participants have completed their quarantine experience and returned to normal life. All three sessions were conducted between April 20 and June 1, 2020, during the beginning of the COVID-19 pandemic and...
tightest restrictions in the United States, so no responses were collected once participants returned to "normal". Additionally, political and social unrest increased during this time in the United States, which may have impacted participants beyond the isolation and confinement caused by the pandemic. We also recognize that we do not have a baseline measurement of positivity, only the measurements taken during the three sessions, so it is impossible to know from these data whether or not participants already felt self-reliant and were not greatly affected by this experience. Other studies of the psychological impacts of the pandemic have not addressed positivity, so despite the stated limitations, we are encouraged by the mirrored reports of depression, anxiety, and stress in other studies [37].

A strength of this study is the timing of data collection during the tightest restrictions to movement and interaction caused by the pandemic, and therefore, the ICE-like environment we were able to capture. In addition, spaceflight analogues are often referred to as isolated, confined, controlled (ICE) environments because they lack the real, ever-present threat and extremity of a space exploration mission [41]. In studying people living in ICE during the COVID-19 pandemic, we observe a group experiencing a real, ever-present threat. In all studies conducted in space analog environments, it is difficult to make broad generalizations based on the results due to perpetually small sample sizes [21,30]. Researchers in this field are caught in a catch-22: the nature of the simulated ICE environment would be corrupted with the addition of participants, but results can only be generalized with high n. The only way around this has been to conduct consecutive campaigns in the same facilities, observing trends between crews. While the sample size for our study is relatively low as compared to studies in other areas of human behavior, we have collected data from 82 participants living in households of ~2–6, aligned in time to have experienced similar levels of isolation and confinement. While we still cannot draw broad generalizations from these results, we can observe trends within these groups that are indicative of the direction this research should take in the future.

5. Conclusion

The differences in self-assessments of psychological state and mood we observed between the GP group and the other two groups suggest that prior experience and training may not have had any bearing on the maintenance of mental health in this participant pool. The difference between the ICEET group and the other two groups in work productivity suggests that the capacity to maintain productivity despite adversity, or resiliency, can be influenced by experience and/or training. The ability to train for resilience and maintain work productivity is important for the success of long-duration crewed space exploration missions. The idea that astronauts will be able to perform their duties effectively and find new ways to be productive during long-duration missions is a positive outcome. Self-assessments of mental health appear to be more impacted by innate characteristics than experience, which is worrisome because it indicates that maintaining mental health is not something we can train for and has the potential to deteriorate over extended periods of isolation and confinement. In addition to the insights into long-duration human spaceflight we stand to gain from this study, the addition of participants, but results can only be generalized with high n. The only way around this has been to conduct consecutive campaigns in the same facilities, observing trends between crews. While the sample size for our study is relatively low as compared to studies in other areas of human behavior, we have collected data from 82 participants living in households of ~2–6, aligned in time to have experienced similar levels of isolation and confinement. While we still cannot draw broad generalizations from these results, we can observe trends within these groups that are indicative of the direction this research should take in the future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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