Astronaut mental health: A review

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## **Abstract**

As space administrations begin preparations for longer term space missions, addressing the potential mental health problems that can arise in astronauts will become mission critical components for future missions. Early American mental health analysis began during NASA’s Project Mercury, astronauts with certain preferred characteristics; both physiological and psychological, would be labeled as “the right stuff.” No longer are our missions confined to short term flights in **LEO** (low earth orbit), but rather ones in preparation for a trek to the red planet. This review attempts to address causes and problems associated with the mental health of astronauts, while concluding with monitoring and mitigation strategies and possible avenues of future research. Problems include: interpersonal disputes among astronauts, missing family, stress, loneliness, depression. These, among others, are problems already faced by astronauts on the **ISS** (International Space Station). Naturally there is an expectation that a future lunar or Mars mission would exacerbate these problems. It is vital that we provide our astronauts with mitigation methods such as: on staff psychologists, mixed **VR**/**VR**(virtual reality) architecture, adjusted exercise routines, special smells. These developments, while a good step forward, and a evidence of progress since the neonatal space psychology research of the Space Race era, it is clear that astronauts need more help before a mission to the red planet is appropriate.

### **Introduction**

Space exploration is very risky. Cosmic rays, micrometeorites, among other things, are constant dangers of human spaceflight. Nevertheless, just as relevant are the within vehicle dangers. Despite their extensive training and preparations, astronauts are still human and can fall victim to the dangers of mental health crises.

Interorganizational endeavors have presented both new opportunities and challenges to mission planners. No longer are space agencies building homogenous teams, but rather across the spectrum, different ethnic, educational, linguistic, national backgrounds. While this provides ample opportunity for joint learning and pride, cultural differences can quickly arise. Consider being an American astronaut on Mir immediately following the Soviet invasion of Afghanistan, flaring tensions could easily derail the mission, or worse bring the superpowers to a new zone of confrontation.

The invention of the semiconductor has brought a litany of new avenues of astronaut health monitoring. Previously, flight surgeons were limited to simple heart rate monitors, cumbersome ground-based machines, and surveys. Currently, mission control use miniature scanners, optical computer recognition technology (from cameras), and other technologies like speech recognition. The future of space monitoring looks to be in the field of advanced biosensors; in-flight data of mental health biomarkers could be vital in helping astronauts mentally survive the hardships of space.

Mitigation techniques encompass both psychological and physiological efforts. Online mental health software modules, modified lighting schemes, occupational therapy, and exercise have all been shown to boost moods in test subjects. As missions become longer and more dangerous, these techniques will need to be used in concert, providing astronauts a fighting chance in **ICE** (isolated, confined, extreme), environments.

The purpose of this literature review is to identify the causes, problems being faced, monitoring methods, and possible solutions to the mental health challenges that astronauts face, and will continue to face in the years ahead. In sifting through academic, government, and industry research this paper will be divided into the four sections labeled in the previous sentence, and attempt to pinpoint the contemporary research, historical context, and ideas for the future to come.

*Isolated, Confined, Extreme*

Isolated, confined, and extreme environments, or ICE environments, have been studied in anecdotal historical accounts [2], laboratory-based simulations [3], [4], and in remote locations [5], [6].

The known effects of ICE environments can be broadly described (for a more thorough investigation, see Pagel 2016 [1]). Before beginning, it must be understood that even under highly controlled conditions, the capacity of humans to withstand ICE effects is profoundly variable. Trends have previously been detected for decreasing positive emotional states, increased depression symptoms, destabilized mood, increased interpersonal conflict, and impaired sleep. Sex differences in these measures, particularly through time, and the confounding effect of the presence of others whose personalities and interpersonal relations must themselves be accounted for, represent noteworthy gaps in our current understanding [7]–[9]. Measures of altered physiology also indicated effects, but these are beyond the scope of the current investigation.

Looking more closely at psychological effects, we can begin to understand their complex, temporal natures. Some of these effects have been shown to reach an asymptote as a function of time, but others (particularly depression symptoms [10], and interpersonal conflicts [11]) often only worsened or manifested far into the experience. New, stabilized, norms may represent a finished adaptation to the environment, or the maximal capacity of the individual to respond to it [12]. In the case of the latter, adaptive strategies (countermeasures) may be employed to increase an individual’s capacity to resist decremental effects [13].

*The lockdowns of COVID-19*

Beginning in early 2020, the international effort to contain the spread of the COVID-19 virus began in earnest. The World Health Organization proclaimed COVID-19 a global pandemic on 11 March 2020 [14], and most US restrictions began shortly thereafter [15]. Richie et. al. published their Stringency Index in late 2020, which quantified the level of restrictions along dimensions of “school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls” [16].

Various regional economic, political, and social pressures would change the specific restrictions and their enforcements. These fluctuating environmental pressures require continual adaptation, suggesting yet another pressure in and of itself [17]. The rise of Delta variant cases of the COVID-19 virus (that constituted another “wave” of the pandemic) was not captured in the present study, yet Figure 2 indicates an oscillation in the severity of the restrictions that could confound time course effects by providing periods of reprieve. Additionally, given the unforeseen arrival of the pandemic, no baseline could be established in any potential subjects. We will attempt to address these concerns in our methodology.

*Effects in a Spaceflight Context*

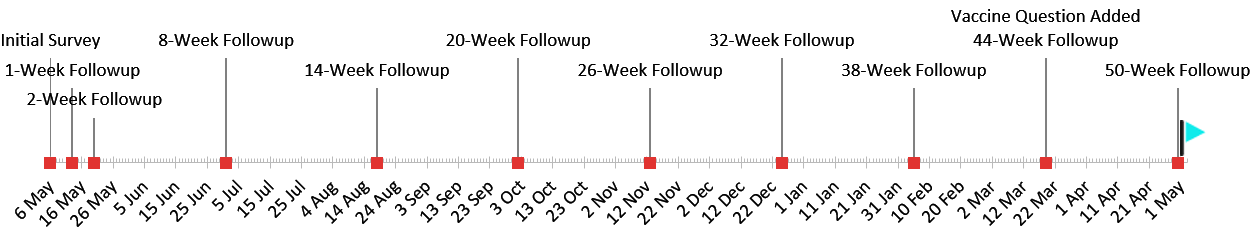
Many of the conditions described above translate readily to the environment of human spaceflight. Astronauts presented with prolonged isolation and confinement will need the most effective countermeasures possible to ensure mission success [18]. These countermeasures must be informed by the most analogous evidence in terms of subjects and environment [19]. While the pandemic is far from a perfect analog, the opportunity to translate the effects of a full year of social lockdowns on the general population should not be overlooked.

Figure : Experimental timeline beginning in 2020 and continuing through 2021. Red squares indicate survey time points.

### · Purpose

The current experiment seeks to reveal the direct effects of prolonged isolation and confinement on individuals during the COVID-19 pandemic as well as model the complex interrelationships of various predisposing factors and coping strategies on these effects.

## METHODS

The online survey was developed in Google Forms. The study was carried out following Texas A&M University IRB approval (IRB2020-0506M). Respondents were gathered via university email system and social media resources. The first distribution to potential respondents went out on 6 May 2020. Subsequent surveys went out only to the pool of initial respondents, and to avoid redundancy, these did not include questions regarding demographics though participants were still asked about their country and/or state of residence. The second distribution occurred one week after the first, then again the following week. After this first batch of three time points, distributions were sent every six weeks subsequent for another year, ending therefore on 6 May 2021. By this final time point, COVID vaccinations in the US had surpassed 65% among adults, and most states had either reduced or remanded all of their lockdown measures, including mandatory mask-wearing requirements. Therefore, the first and final time points of data collection may be considered a “during” and “after” lockdown, respectively. An experimental timeline can be seen in Figure 1 below. Following the release of any survey, subjects had one week in which to log their response before the survey closed.

### · Respondents

96 subjects responded to the initial call. Of these 96, 84 responded to subsequent calls at least once, and six subjects responded to all eleven survey distributions. 58.3% were female. The mean age was 41.66 y. (+/- 15.22). 65 of the respondents lived in the United States, 21 in Spain, 3 in Canada, and no other country had more than 1 respondent. 57 subjects reported earning at least a Master’s degree, with 75 holding at least a Bachelor’s degree. 38 reported living with at least one child, though the ages of any children was not requested. 16 respondents reported living with at least one person over the age of 65 (not including themselves).

The first follow-up survey garnered 40 respondents. After this, surveys received an average of 25 +/- 4.5 respondents. One will note that a full factorial analysis on these respondents is often belied by the diminishing number of responses such that even binary factors suffer from low statistical power and therefore any value in extrapolation. For this reason, as detailed below, only broad interpretations on the subject pool can be made.

### · Survey Sub-sections

The survey was divided into sections related to individual lifestyle, social, and professional parameters as well as personality and mood. These tools were chosen as they are often used in space analog [4], [20]. Sub-sections were as follows:

* Demographics from the initial survey included age, biological sex, country of living (and state, if applicable), educational level, living situation, household, and employment status.
* UCLA Loneliness Scale, a 20-item tool for measuring subjective feelings of social isolation on a scale from 20-80, though our version of the survey mistakenly included 19 items. Individual questions use a 4-point Likert scale with higher numbers indicating greater agreement with preceding statements. These scores are summed for a final metric of loneliness [21].
* The Profile of Mood States, a 32-item tool with six subscales measuring tension, confusion, depression, anger, fatigue, and vigor. Single word prompts are given and subjects rank their feeling of current state agreement with the prompt on a Likert scale of 0 to 4 [22], [23].
* The Pittsburgh Sleep Quality Inventory, a 19 item tool with 7 subscales: subjective sleep quality, sleep latency (time to fall asleep), sleep duration, sleep efficiency (ratio of time in bed by sleep duration), sleep disturbance, use of sleep medication, and daytime dysfunction. Each component is scored 0 to 3, with higher numbers indicating greater sleep difficulty. An overall sum of 5 or higher indicates poor sleep. While the typical PSQI is used over an interval of one month, the current version was adapted by Beck et al. (2004) to use a one-week interval [24], [25].
* The International Physical Activity Questionnaire (short-form) calculates an overall physical activity score based on time and intensity, with a separate question for total seated minutes. It reflects only activity over the preceding 7 days [26].
* The State Trait Anxiety Inventory is a 40-item tool with scales for State anxiety (for current state) and Trait Anxiety (for overall personality bias toward anxiety). Only the 20-item State subscale was used for this study. Scores range from 20-80 with higher scores indicating greater state anxiety. Clinically, a score of 39-40 has been suggested for detecting clinically-significant symptoms, though other studies have suggested much higher: 54-55 [27].
* A section on the use of stimulating substances such as alcohol, tobacco, and caffeine. This section only considered the previous 7 days. Subjects were also asked whether the lockdown had effected their habits in these areas. Outcomes included daily cups of coffee, glasses per day of liquor, wine, beer, and “other caffeinated beverages”, as well as daily cigarette intake.
* A section related to the pandemic itself. These questions asked respondents to rank their agreement with statements regarding the pandemic. These included whether they thought the pandemic would last long, if they trusted authorities to handle the crisis, if they perceived the virus to be a life-threatening disease, if they believed any conspiracies surrounding the pandemic, and whether or not they had been effected, knew someone close to them who had contracted the virus, or experienced the death of someone close to them due to the virus.
* A section on the salutogenic effects of the lockdown. Respondents were asked whether they had perceived any positive effects of the situation on their life and could answer with a simple yes or no. Potential effects included time for exercise, time for family, or the ability to participate in online courses. At the time of this writing, this section has not yet been analyzed.

The complete survey and anonymized data set can be found (for the purposes of this paper) in a Google Drive folder [HERE](https://drive.google.com/drive/folders/19_BvPypGuaFgVlDfIAK5qnWlgUTSSv6a?usp=sharing).

### · Data analysis

Alpha levels of 0.05 were used for all tests. Data was tested using Matlab (2015, 2016, 2020 and 2021 versions, Natick, Massachusetts: The MathWorks Inc.) and SPSS (1.27, IBM Corp). Directions to view the Matlab code used herein can found in the Appendix.

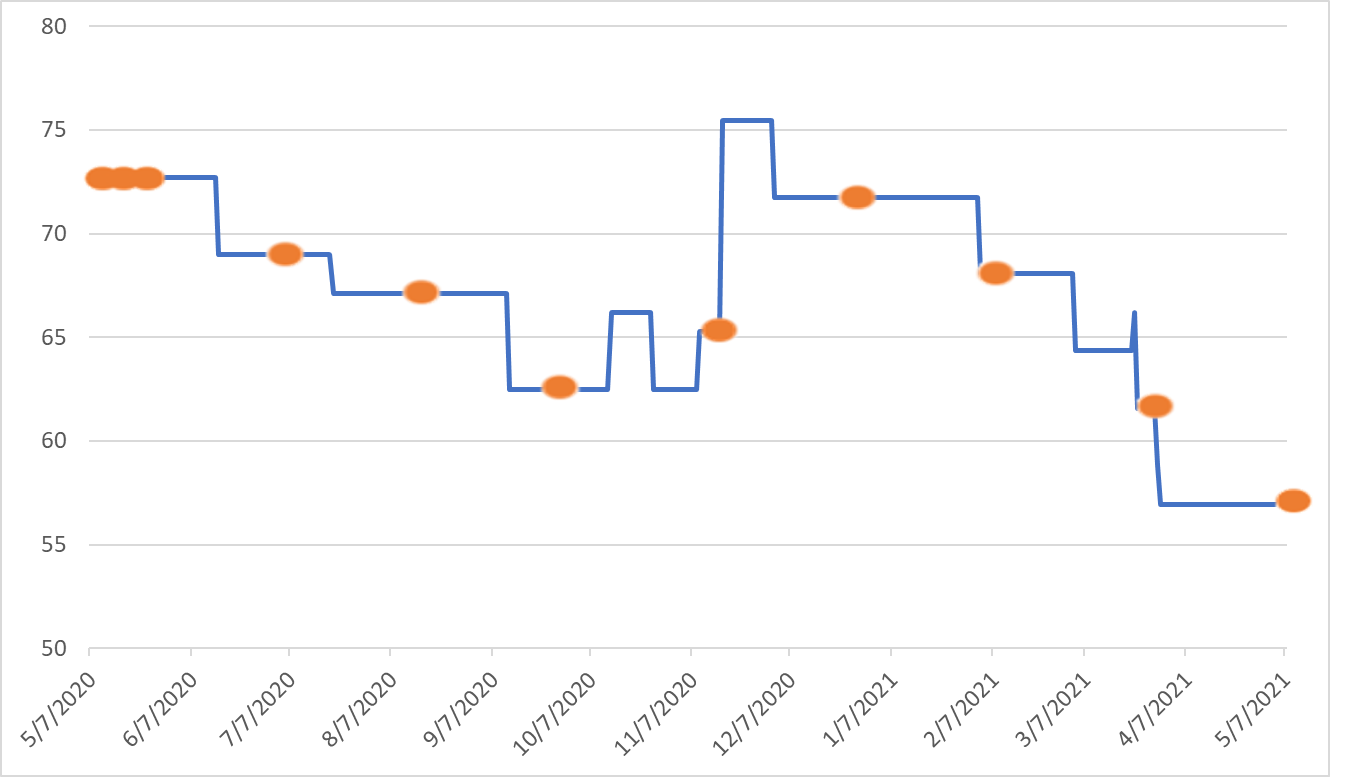
Changes through time were analyzed with one-way between-subjects analysis of variance tests where assumptions were verified, or two-way ANOVA when SEX and ALONE factors were included. Following detection of significant variance differences, Tukey’s post hoc analysis was performed to determine pairwise levels of significance, with a Bonferonni correction for multiple comparisons.

Figure : Experimental timeline with associated Stringency Index (blue line) and survey time points (orange circles).

Where parametric assumptions could not be verified, non-parametric Kruskall Wallis tests were used to analyze time effects, with a series Wilcoxon rank tests to further elucidate significant levels when detected. Mann-Whitney U tests were used to analyze SEX and ALONE effects comparing all data points at all time points, with a Bonferonni correction for multiple comparisons. Wilcoxcon rank sum tests were also performed when comparing non-parametric measures between SEX and ALONE groups, using the entire data set’s responses.

Subsequent comparisons of median differences of dependent variables at each time point were normalized to Stringency Index (SI) by first taking the product of the measure and the SI of the United States at that time. Time point medians of this SI-adjusted product were tested via K-W analysis as per above and, in some cases, yielded a different result. Only U.S. respondents were used for this comparison.

Correlations are reported using coefficients of determination.

## RESULTS

Figure 2 summarizes the Stringency Index used to adjust certain time comparisons in the following data. SI values during our survey ranged from 56.94-72.69 with a mean change of 4.28 (+/- 1.65) from one time point to the next following the first cluster of 3 surveys.

### Spaceflight Applicability

Among the initial respondents, it is worth noting that the average age (41 +/- 15 y.) and education level (78% had at least a bachelor’s degree, 45% had at least a master’s degree) is comparable to an astronaut-like population. 58% of the initial respondents were female and this ratio was generally preserved throughout the time course of the survey.

### · A Year In Lockdown Data

Table 1 summarizes the analysis conducted on the comparisons of means (in the case of parametric analysis) or medians (for non-parametric analysis) across the time of the survey to determine any effects of non-SI-adjusted time on all respondents as a single group.

Table 1 : Summary of variances of selected measures over time. Signficant results are elaborated in the text.

|  |  |  |
| --- | --- | --- |
| **Measure** | **Test Used** | **Result**  **(p-value)** |
| Anxiety;  SI-Adjusted | Kruskal-Wallis  Kruskal-Wallis | 0.524  *0.001* |
| Tension | Kruskal-Wallis | 0.922 |
| Depression | Kruskal-Wallis | 0.602 |
| Loneliness;  SI-Adjusted | ANOVA  ANOVA | *< 0.001*  *< 0.001* |
| Sleep Quality | ANOVA | *< 0.001* |
| Vigorous Exercise Days | Kruskal-Wallis | 0.9969 |
| Time/Day - Vigorous Exercise | Kruskal-Wallis | 0.9898 |
| Moderate Exercise Days | Kruskal-Wallis | 0.9969 |
| Time/Day - Moderate Exercise | Kruskal-Wallis | 0.9948 |
| Walking Days | Kruskal-Wallis | 1 |
| Time/Day - Walking | Kruskal-Wallis | 0.9898 |
| Time/Day - Sitting | Kruskal-Wallis | *0.0360* |
| Total Exercise | Kruskal-Wallis | 0.9898 |
| Tobacco Use | Insufficient data to run tests | N/A |
| Beer Use | Kruskal-Wallis | 0.9999 |
| Wine Use | Kruskal-Wallis | 0.9999 |
| Liquor Use | Kruskal-Wallis | 0.9999 |
| Tea Use | Kruskal-Wallis | 0.9951 |
| Coffee Use | Kruskal-Wallis | 0.9915 |
| Other Stimulant Beverage Use | Kruskal-Wallis | 0.9841 |
| Crisis Length Expectancy | Kruskal-Wallis | 0.5887 |
| Trust In Authorities | ANOVA | 0.1640 |
| Compliance with Lockdown | Kruskal-Wallis | 0.9774 |
| Seriousness of COVID-19 Threat ;  SI-Adjusted | Kruskal-Wallis  Kruskal-Wallis | 0.8507  *<0.001* |

*Mood States & State Anxiety*

Analyzing the POMS categories for each of the mood states, the majority of the POMS did not change over time. Depression, Anger, Tension, Vigor and Fatigue did not see any overall change over time on an individual level. Running a Kruskal-Wallis test leads to none of the POMS having a significant change over time. However, the State Anxiety did see a decrease over week 0 to week 48 the final week of the survey. SI-adjusted Anxiety further showed decreases at week 42 over week 0.

*Loneliness*

Loneliness tended to decrease over time, with significantly lower states at weeks 48 when compared to week 1, but the SI-adjusted comparison revealed additional decreases at week 18 and 42 when compared to weeks 0 and 1.

*Physical Activity*

Other than time spent sitting, no physical exercise category changed over time. Time spent sitting showed a slight decrease over time. But otherwise, no other statistically significant results were found. All these tests were run using a Kruskal-Wallis after checking to see if the data was parametric. Time spent sitting had a null hypothesis of, “no change over time”, however a p-value of 0.0360, leads us to reject the null hypothesis, and claim that there is a difference in time spent sitting across time. All other p-values were larger than .98.

*Stimulant Use*

None of the stimulant use showed any change over time. Tobacco was not tested as a stimulant due to insufficient data- nearly all responses over the survey were “none”. All tests were run using a Kruskal-Wallis test after checking the data for parametricity. All p-values were larger than 0.98.

*Covid-19*

SI-adjusted comparison of the COVID-19 threat assessments showed diminished values at weeks 12, 18, and 48 when compared to week 0. Week 48 was also lower than weeks 1 and 30.

### Sex Differences

Respondents self-identified their preferred SEX as either “Male”, “Female”, or “Undecided/Prefer Not To Say” in the initial survey and this question was not repeated in subsequent surveys. Owing to the low sample size of the latter category (Median = 0), it could not be included in statistical analyses. Therefore, this dimension was analyzed in a binary fashion as either “Male” or “Female” only. Table 2 summarizes the results of sex comparisons across all time points, and Figure 3 displays any detected differences at each time point of the survey. However, 2-ways analyses of variance for SEX x TIME were not conducted for this paper, nor are they SI-adjusted.

Table 2 : Comparisons of central tendency by sex at all collected time points.

|  |  |  |
| --- | --- | --- |
| **Measure** | **Test Used** | **Result**  **(p-value)** |
| Loneliness | Wilcoxon Rank-Sum | 0.0996 |
| Sleep Quality | Wilcoxon Rank-Sum | *< 0.001* |
| Anxiety | Wilcoxon Rank-Sum | *< 0.001* |
| Tension | Wilcoxon Rank-Sum | *< 0.001* |
| Depression | Wilcoxon Rank-Sum | *0.0042* |
| Anger | Wilcoxon Rank-Sum | 0.2606 |
| Fatigue | Wilcoxon Rank-Sum | *< 0.001* |
| Vigor | Wilcoxon Rank-Sum | *< 0.001* |
| Sleep Quality | ANOVA | *< 0.001* |
| Vigorous Exercise Days | Wilcoxon Rank-Sum | *< 0.001* |
| Time/Day - Vigorous Exercise | Wilcoxon Rank-Sum | *0.0025* |
| Moderate Exercise Days | Wilcoxon Rank-Sum | 0.4699 |
| Time/Day - Moderate Exercise | Wilcoxon Rank-Sum | 0.9476 |
| Walking Days | Wilcoxon Rank-Sum | 1 |
| Time/Day - Walking | Wilcoxon Rank-Sum | 0.7928 |
| Time/Day - Sitting | Wilcoxon Rank-Sum | 0.7928 |
| Total Exercise | Two sample T-test | *0.0017*  *(means)*  *0.0021*  *(medians)* |
| Tobacco Use | Insufficient data to run tests | N/A |
| Beer Use | Wilcoxon Rank-Sum | 0.2739 |
| Wine Use | Wilcoxon Rank-Sum | 0.2599 |
| Liquor Use | Wilcoxon Rank-Sum | *0.0193* |
| Tea Use | Wilcoxon Rank-Sum | 0.6682 |
| Coffee Use | Wilcoxon Rank-Sum | *0.0031* |
| Other Stimulant Beverage Use | Wilcoxon Rank-Sum | *0.0445* |
| Crisis Length Expectancy | Wilcoxon Rank-Sum | *<0.001* |
| Seriousness of COVID-19 Threat | Wilcoxon Rank-Sum | *0.0027* |

*POMS Depression*

Using a Wilcoxon Rank sum test compared all the male variables to all the female variables, testing was based on the null hypothesis that males and females experienced the same levels of depression. With a p-value of 0.0042 rejected the null hypothesis and led to belief that there was a difference between male and female with females having larger levels of depression. As seen in Figure 3, panel a, males and females began with similar scores but quickly diverged and remained separated throughout.

*POMS Vigor*

Vigor comparison was done comparing columns of Male data to female data utilizing the Wilcoxon rank sum test, running this test with the null hypothesis that Male and female experienced the same amount of vigor. The low p-value led to a rejection of null hypothesis. The largest separation in sex as seen in figure 3, panel b, with a p-value much less than 0.001 means a likely a large difference in vigor experienced by each sex.

*POMS Tension*

Tension also had a high degree of difference between the males and females. This was tested with the Wilcoxon Rank-sum test to yield a p-value much less than 0.001. The null hypothesis tested was if each sex experienced the same level of Tension. With the low p-value calculated we rejected the null hypothesis in favor of the difference between male and female tension experienced as can be seen in figure 3, panel c, with females staying nearly always above males on all time points.

*POMS Fatigue*

Fatigue varied from one sex to the other as well upon testing. Using the Wilcoxon Rank sum test to compare both data sets. We reject the null hypothesis that both male and females experienced the same amount of fatigue. Looking at figure 3, panel d, we can see that females tend to have increased median fatigue compared to males over the time period.

*POMS Anger*

Analysis of Anger did not yield statistically significant results after not being able to reject the null hypothesis that both genders experienced the same anger due to p-value greater than 0.05.

*State Anxiety*

State Anxiety comparison led to the likelihood that females experienced higher levels of anxiety than the males, testing all females vs the males with the Wilcoxon rank sum test with the null hypothesis that males and females experienced the same levels of anxiety. With the p-value much less than 0.001 we reject the null hypothesis in favor of likelihood that there is a difference between sexes. Looking at figure 3, panel e, can see that females tended to be higher on nearly all data points.

*Physical Activity*

After checking the data for parametricity and testing with a Wilcoxon Rank Sum test, a null hypothesis where men and women exercised the same, a p-value of < 0.001 was returned. As seen in figure 3, panel i, we can see that men spent more days of the week engaging in vigorous physical exercise.

The time spent per day of vigorous exercise was tested under the null hypothesis that men and women spent equal amounts of time vigorously exercising. Returning a p-value of 0.0025 from a Wilcoxon Rank Sum, we reject the null hypothesis and take note that in figure 3, panel k, on days of vigorous exercise men spent more time vigorously exercising.

For a dataset of days spent moderately exercising, the data was tested for parametricity, and a null hypothesis stating men and women spent the same number of days moderately exercising. Using a statistical Wilcoxon Rank Sum test, we report a p-value of 0.4699 and fail to reject the null hypothesis.

The time spent per day of moderate exercise was tested under the null hypothesis that men and women spent equal amounts of time moderately exercising. Returning a p-value of 0.9476 from a Wilcoxon Rank Sum, we fail to reject the null hypothesis.

For a dataset of days spent walking, the data was tested for parametricity, a null hypothesis stating men and women spent the same number of days walking, and a statistical Wilcoxon Rank Sum test, we saw a p-value of 1 and failed to reject the null hypothesis.

The time spent per day of walking was tested under the null hypothesis that men and women spent equal amounts of time per day walking. Returning a p value of 0.7928 from a Wilcoxon Rank Sum, we fail to reject the null hypothesis.

The time spent per day sitting was tested under the null hypothesis that men and women spent equal amounts of time sitting. Returning a p value of 0.7928 from a Wilcoxon Rank Sum, we fail to reject the null hypothesis.

Total exercise was tested using a 2-sample t-test on both means and median data. A null hypothesis claimed that both men and women had an equal total exercise value. However, with returned p-values of 0.0017 for the mean data set and 0.0021 for the median data set, we can safely reject the null hypothesis. As seen in figure 3, panel j, we note that men scored higher on their total exercise value than women.

*Stimulant/Depressant Use*

As mentioned above, there was insufficient data to run tests as the median respondent did not report any tobacco use.

Number of glasses of beer drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that men and women drank the same number of glasses of beer per day. A returned p-value was equal to 0.2739 so we fail to reject the null hypothesis.

Number of glasses of wine drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that men and women drank the same number of glasses of wine per day. A returned p-value was equal to 0.2599 so we fail to reject the null hypothesis.

Number of glasses of liquor drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that men and women drank the same number of glasses of liquor per day. A returned p-value was equal to 0.0193 so we reject the null hypothesis. As seen in figure 3, panel n, we note that women are having more glasses of liquor than men.

Number of cups of tea drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that men and women drank the same number of cups of tea per day. A returned p-value was equal to 0.6682 so we fail to reject the null hypothesis.

Number of cups of coffee drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that men and women drank the same number of cups of coffee per day. A returned p-value was equal to 0.0031 so we reject the null hypothesis. As noted in figure 3, panel m, we see that men drink more cups of coffee than women do.

Number of cans of other caffeinated drinks drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that men and women drank the same number of cans of caffeinated drinks per day. A returned p-value was equal to 0.0445 so we reject the null hypothesis. Seen in figure 3, panel l, we note that women are drinking more cans of caffeinated drinks than men.

*COVID-19*

Many of the COVID related questions did not produce a statistically significant difference between males and females. The only question that produced parametric data was the one that inquired the extent to which they trusted authorities. A 2-tailed t-test was conducted between the means and medians which produced p values of 0.8483 and 0.3252 respectively thus the null hypothesis of no differences between sexes could not be rejected. For all other questions, a Wilcoxon Rank Test was conducted and resulted in p-values greater than 0.05 thus no difference could be concluded between females and men.

One difference between females and males was found in the expectancy of the length of the crisis and the perception of the seriousness of the coronavirus threat. As can be seen in figure 3, panel g, women were more likely to think the crisis would last long and perceived the coronavirus as a more serious threat.

*UCLA Loneliness*

Loneliness was tested both with means and median data. A null hypothesis claimed that both men and women felt lonely equally. The Wilcoxon Ranksum test returned p values of 0.1486 for the mean data set and 0.0996 for the median data set; this demonstrates the null hypothesis cannot be rejected. The test showed no significant difference between males and females regarding loneliness.

*Sleep Quality*

The PSQI dataset was tested both with means and median data. A null hypothesis claimed that both men and women have equal sleep quality. The Wilcoxon Rank sum test returned p values of less than 0.001 for the mean data set and the median data set; this demonstrates the null hypothesis is rejected. According to figure 3, panel h, we can see that males seem to have better quality of sleep as demonstrated by lower overall PSQI scores.

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Figure 3 : Comparisons of male (blue lines) and female (pink lines) respondent means (with SE) over time (x-axis, listed by week with the initial survey as ‘0’). Dashed lines represent medians. Panels are titled. Yes, they can be hard to read…but we spent so long trying to get this right…

### The Effect of Others

Respondents reported the number of other people living in their home. For the purposes of this comparison, those living with no other people were given a score of 0, and those living with any other people (adults or children) were given a score of 1. Table 3 summarizes the results of ALONE comparisons across all time points, and Figure 4 displays any detected differences at each time point of the survey. However, 2-ways analyses of variance for ALONE x TIME were not conducted for this paper, nor are they SI-adjusted.

Table 3 : Comparison of central tendency by alone score at all collected time points.

|  |  |  |
| --- | --- | --- |
| **Measure** | **Test Used** | **Result**  **(p-value)** |
| Loneliness | Wilcoxon Rank-Sum | *0.0018* |
| Sleep Quality | Wilcoxon Rank-Sum | *< 0.001* |
| Depression | Wilcoxon Rank-Sum | 0.0426 |
| Vigor | Wilcoxon Rank-Sum | *< 0.001* |
| Sleep Quality | ANOVA | *< 0.001* |
| Vigorous Exercise Days | Wilcoxon Rank-Sum | 0.5495 |
| Time/Day - Vigorous Exercise | Wilcoxon Rank-Sum | *0.0378* |
| Moderate Exercise Days | Wilcoxon Rank-Sum | *0.0025* |
| Time/Day - Moderate Exercise | Wilcoxon Rank-Sum | 0.5261 |
| Walking Days | Wilcoxon Rank-Sum | 0.2451 |
| Time/Day - Walking | Wilcoxon Rank-Sum | 0.1131 |
| Time/Day - Sitting | Wilcoxon Rank-Sum | *< 0.001* |
| Total Exercise | Two sample T-Test (mean)  Two sample T-Test (median) | 0.3239  0.2512 |
| Tobacco Use | Insufficient data to run tests | N/A |
| Beer Use | Wilcoxon Rank-Sum | 0.9716 |
| Wine Use | Wilcoxon Rank-Sum | 0.7568 |
| Liquor Use | Wilcoxon Rank-Sum | *0.0423* |
| Tea Use | Wilcoxon Rank-Sum | *0.0123* |
| Coffee Use | Wilcoxon Rank-Sum | *0.0021* |
| Other Stimulant Beverage Use | Wilcoxon Rank-Sum | 0.0901 |
| Crisis Length Expectancy | Wilcoxon Rank-Sum | *0.0016* |
| Trust In Authorities | 1 Tailed t-test (means)  1 Tailed t-test (medians) | *0.0052*  *0.0119* |

*POMS Depression*

The effect of not living alone on depression level was shown to have an effect. Through a Wilcoxon rank sum test with null hypothesis tested that living alone and not living alone experienced same level of depression. With a p-value of 0.0426 we rejected the null hypothesis in favor of likelihood that there was a difference between the two. Looking at figure 4, panel a, we can see that with a plot of the means that those living alone tended to have a larger depression level.

*POMS Vigor*

Vigor was found to likely be higher for those who lived with others. Using the Wilcoxon rank sum we tested the null hypothesis that vigor was the same for those living alone and not alone. We reject the null hypothesis with a p-value much less than 0.001. Looking at figure 4, panel b, those living with others tended to have higher vigor than those living alone.

*State Anxiety*

The effect of living with others was found to again be significant for state anxiety. Utilizing Wilcoxon rank sum test the null hypothesis that living with others or alone had the same levels of anxiety, this hypothesis was rejected. As seen in figure 4, panel c, those living alone tended to have higher anxiety.

*Physical Activity*

For a dataset of days spent vigorously exercising, the data was tested for parametricity, a null hypothesis stating those who live alone and those who live with others spent the same number of days vigorously exercising, and a statistical Wilcoxon Rank Sum test, we saw a p-value of 0.5495 and failed to reject the null hypothesis.

The time spent per day of vigorous exercise was tested under the null hypothesis that those who live alone and those who live with others spent equal amounts of time vigorously exercising. Returning a p-value of 0.0378 from a Wilcoxon Rank Sum, we reject the null hypothesis and take note that in figure 4, panel i, on days of vigorous exercise those who live alone spent more time vigorously exercising.

For a dataset of days spent moderately exercising, the data was tested for parametricity, a null hypothesis stating those who live alone and those who live with others spent the same number of days moderately exercising, and a statistical Wilcoxon Rank Sum test, we saw a p-value of 0.0025 and therefore we reject the null hypothesis.

As noted in figure 4, panel h, those who lived with others spent more days moderately exercising than those who lived alone.

The time spent per day of moderate exercise was tested under the null hypothesis that those who live alone and those who live with others spent equal amounts of time moderately exercising. Returning a p-value of 0.5261 from a Wilcoxon Rank Sum, we fail to reject the null hypothesis.

For a dataset of days spent walking, the data was tested for parametricity, a null hypothesis stating those who live alone and those who live with others the same number of days walking, and a statistical Wilcoxon Rank Sum test, we saw a p-value of 0.2451 and failed to reject the null hypothesis.

The time spent per day of walking was tested under the null hypothesis that those who live alone and those who live with others spent equal amounts of time per day walking. Returning a p-value of 0.1131 from a Wilcoxon Rank Sum, we fail to reject the null hypothesis.

The time spent per day sitting was tested under the null hypothesis that those who live alone and those who live with others spent equal amounts of time sitting. Returning a p-value of < 0.001 from a Wilcoxon Rank Sum, we reject the null hypothesis. We note in figure 4, panel j, people who live alone spend more time sitting than those who live with others.

Total exercise was tested using a 2 sample t test on both means and median data. A null hypothesis claimed that both those who live alone and those who live with others had an equal total exercise value. However, returned p-values of 0.3239 for the mean data set and 0.2512 for the median data set, we fail to reject the null hypothesis.

*Stimulant/Depressant Use*

As mentioned above, no tests were conducted on tobacco use.

Number of glasses of beer drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that those who live alone and those who live with others drank the same number of glasses of beer per day. A returned p-value was equal to 0.9716 so we fail to reject the null hypothesis.

Number of glasses of wine drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that those who live alone and those who live with others drank the same number of glasses of wine per day. A returned p-value was equal to 0.7568 so we fail to reject the null hypothesis.

Number of glasses of liquor drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that those who live alone and those who live with others drank the same number of glasses of liquor per day. A returned p-value was equal to 0.0423 so we reject the null hypothesis. As seen in figure 4, panel m, we note that those who live alone drink more glasses of liquor than those who live with others.

Number of cups of tea drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that those who live alone and those who live with others drank the same number of cups of tea per day. A returned p-value was equal to 0.0123 so we reject the null hypothesis. We note in figure 4, panel n, that those who live with others drink more tea than those who live alone.

Number of cups of coffee drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that those who live alone and those who live with others drank the same number of cups of coffee per day. A returned p-value was equal to 0.0021 so we reject the null hypothesis. As noted in figure 4, panel l, we see that those who live with others drink more coffee than those who live alone.

Number of cans of other caffeinated drinks drunk in the last 7 days was tested using a Wilcoxon Rank Sum test with the null hypothesis that those who live alone and those who live with others drank the same number of cans of caffeinated drinks per day. A returned p-value was equal to 0.0901 so we fail to reject the null hypothesis.

*COVID-19*

Most COVID-19 related questions were not affected by the living status of individuals. Compliance with lockdown protocol (p = 0.0522), and perception of the seriousness of the threat (p = 0.0558) produced p-values that were nearly significant results using a Wilcoxon Rank-Sum test.

The agreement to the question “Do you think the crisis will last long?” was different between individuals living alone and living with others. As can be observed in figure 4, panel d, people who were living alone thought the crisis would last longer. Similarly, in figure 4, panel e, it can be observed that trust in authorities was greater in those not living alone. This is supported by the statistical tests shown in the table above.

*UCLA Loneliness*

UCLA loneliness was tested both with means and median data. A null hypothesis claimed that those who lived alone and those who lived with others felt lonely equally. The Wilcoxon Rank sum test returned p-values of 0.0018 for the mean data set and less than 0.001 for the median data set; this demonstrates the null hypothesis is rejected. The test showed significant differences between the two groups. regarding loneliness. From figure 4, panel f, the data showed that those who are alone tend to feel lonelier.

*Sleep Quality*

The PSQI dataset was tested both with means and median data. Using the null hypothesis which claimed that those who lived alone and those who lived with others have equal sleep quality. The Wilcoxon Rank sum test returned p values of less than 0.001 for the mean data set and the median data set; this demonstrates the null hypothesis is rejected. According to figure 4, panel g, the data showed that people living with others tend to have better quality of sleep.

## DISCUSSION

The findings of this project have shed light on effects of time, sex, and the company of others on various psychological and behavioral outcomes pertinent to well-being and performance. The social restrictions necessary to recover from the COVID-19 pandemic presented a novel environment in which to study these effects in the general population. This is potentially novel not only due to the guarantee of anonymity to the experimenters, (the lack of which could bias responses,) but also due to the ongoing lifestyle demands of the subjects which were unique to each of them and provided a way to glean insight into the way people adapt to sustained, novel pressures in addition to the pressures they were accustomed to.

*Generalized Effects*

Analysis demonstrated a very high degree of variability between subjects when compared as an entire group. This well-educated sample population of mostly working adult professionals seemed to meet the challenges of social restrictions with mixed degrees of success. Whether this is due to an underlying resilience (or lack thereof) reflected in their personality [28], [29], or the effect of coping strategies, is impossible to titrate with the current data. It is quite possible that a larger sample size could elucidate statistical differences, but it is unlikely that a pandemic of this magnitude will strike again anytime soon [30].

Nevertheless, the data does seem to tease at the notion of individuals with a fortitude against ICE environments. Such individuals have been noted in analogous studies of the same effects [3], [31], including similar studies to ours during the COVID-19 pandemic [32]–[34]. Such individuals, whether endowed with inherent personality traits or equipped with intentional behavior strategies, would make ideal crew members for missions in ICE environments if these features could be discovered.

*Sex Differences*

Outcomes for women were notably worse than those of men, a finding that aligns with emerging data from the COVID-19 pandemic [35]. It is possible that an unintended sampling bias owing to the relative few men at a given survey time point is responsible for some of these effects, but the weight of the evidence seems to support the notion of significant sex differences favoring men in ICE environments and analogs. Women showed higher levels of depression, anxiety, tension, and fatigue, also keeping with previous studies [36]. Their vigor and sleep quality were lower than that of men, and sleep is a factor of health [37], [38]. They also reported drinking more liquor. Men, in contrast, exercised more (a proven strategy in ICE resilience [39], [40]) and more vigorously. Men reported drinking more coffee. While men’s anxiety scores steadily diminished over time, women’s anxiety scores either held steadfast or increased.

One could speculate that these outcomes reflect a more gregarious inclination in women [41], and that social restrictions would more strongly effect those who are more socially inclined, though it should be noted that both sexes reported similar loneliness. Another explanation is suggested by the evidence that women believed the COVID-19 crisis would last longer than men did. Men tended to show higher trust in the authorities responsible for guiding us out of the crisis, and could therefore have resigned themselves to a more hopeful disposition.

*The Effect of Others*

It is clear from this data that social dynamics play an important role in human health. Individuals who reported living alone, and thus potentially removed from professional and personal contacts, reported higher levels of depression, anxiety, liquor consumption, and loneliness. They demonstrated lower vigor and sleep quality. While people living alone reported more time spent performing vigorous exercise, they also spent more time sitting. Work from Borrega-Mouquinho et. al. (2021) on the effect of high- vs. moderate intensity at-home exercise during the pandemic indicated that greater intensity was associated with greater psychological benefits, yet this did not appear to outweigh the effect of living alone in our data set [42].

These findings only underscore the volumes of data indicating the critical importance of our social structures to our well-being [43]–[47]. Whether family, friends, professional, or even social contact in passing, the human experience is (without putting too fine a point on it) chiefly a shared one. None of the subjects who indicated living alone improved on the metrics we have presented herein over the course of the study. This suggests that it is a rare person indeed who could thrive under such conditions for long.

### · Shortcomings

SI-adjusted time effects suggest an effect of SI on our measures. To elucidate these effects and their relative weights, multi-factor modeling is warranted. Owing to the variability of responses, the comparison of data week-to-week was difficult to parse. Additionally, the different respondents at each time point warranted a between-subjects approach, weakening the statistical power of the data set.

Human variability, especially along psycho-behavioral axes, often require very large sample sizes to truly isolate single effects. The current study was performed alongside several European counterparts but only for the first three time points. Still, the careful incorporation of this data could shed light on some of the early effects of the social restrictions.

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