UNIVERSITY OF CALIFORNIA

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# Evaluation of Space Food for Commercial Astronauts

A dissertation submitted in partial satisfaction of the

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in Psychology

by

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ABSTRACT OF THE DISSERTATION

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As commercial aerospace companies advance toward manned spaceflight, they must overcome many hurdles – not only technical, but also human. One of the greatest human challenges they face is food. Throughout the history of human spaceflight, astronauts have primarily eaten food developed by government space agencies. Now, with manned commercial flights on the horizon, astronauts will be provided with an entirely new diet – one comprised of commercially available, ready-to-eat food. Yet will this diet keep astronauts nourished, satisfied with their diet, and both psychologically and physically healthy? The purpose of this parallel crossover design study was to evaluate (a) nutrient intake, (b) food satisfaction, (c) psychological health, and (d) physical health in commercial aerospace employees (N = 7) as they ate a diet of commercial, ready-to-eat food for four days, as compared to eating as normal for four days.

Findings from this study showed that the ready-to-eat diet did not lead to any significant changes in caloric intake, psychological health, or physical health, aside from weight loss. It is not clear whether this weight loss was due to the loss of body fat, muscle, or water. When eating

the ready-to-eat food, participants reported being slightly less satisfied with the variety, reported lower cravings for sweets, and reported the food was slightly less hedonically rewarding. In post-study interviews, participants reported they wanted to see more meats, fruits, vegetables, and desserts added to the ready-to-eat diet, so as to provide more meal-like structure. Overall, these findings show the diet could be used in commercial spaceflight after making simple changes. The diet could also be used by individuals in remote areas on Earth and to provide food assistance to individuals in disaster or emergency situations. Due to the increasing popularity of ready-to-eat food around the world, these findings also provide knowledge about the potential consequences of modern eating trends.

The dissertation of Britt Karin Ahlstrom is approved.

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2016

This manuscript is dedicated to my parents.

*We're made of star stuff. We are a way for the cosmos to know itself.* – Carl Sagan

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Disclaimer: This research was funded by SpaceX. I, the author, am a stockholding employee at SpaceX, the company whose employees participated in the study described in this manuscript. However, I did not receive and will not receive any financial rewards or penalties based on the study results. In agreement with SpaceX's Legal team, descriptions of individual food items have been generalized to protect Confidential Information.

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*Management and Resilience Training for Flight Controllers.* Poster presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

**Ahlstrom, B.**, Wagner, H. S., Redden, J. P., Vickers, Z., & Mann, T. (2015, January). *The Potential for Food to Reduce Stress and Increase Consumption On-Ground and In-Flight On Long-Duration Missions.* Poster presented at the NASA Human Research Program Investigators' Workshop, Galveston, TX.

Wagner, H. S., **Ahlstrom, B.**, Redden, J. P., Vickers, Z. & Mann, T. (2014). The myth of comfort food. *Health Psychology, 33*(12), 1552-1557. doi: 10.1037/hea0000068

Scherschel, H., **Ahlstrom, B.**, Mann, T., Redden, J., & Vickers, Z. (2013, August). *Do Comfort Foods Repair Bad Moods?* Poster presented at the 10$^{th}$ Panghorn Sensory Science Symposium, Rio de Janeiro, Brazil.

Tomiyama, A. J., **Ahlstrom, B.**, & Mann, T. (2013). Evaluating eating behavior treatments by FDA standards. *Frontiers in Psychology, 4*(1009). doi: 10.3389/fpsyg.2013.01009

Tomiyama, A. J., **Ahlstrom, B.**, & Mann, T. (2013). Long-term effects of dieting: Is weight loss related to health? *Social and Personality Psychology Compass, 7*(12), 861-877. doi: 10.1111/spc3.12076.

Evaluation of Space Food for Commercial Astronauts

As commercial aerospace companies advance toward manned spaceflight, they must overcome many hurdles – not only technical, but also human. One of the greatest human challenges they face is food.

Providing astronauts with nourishing and appetizing food has been a challenge ever since human spaceflight began in 1961. At that time, little was known about how eating would work in a weightless environment (Lane & Feeback, 2002; Perchonok & Bourland, 2002). Would astronauts be able to swallow? Would they be able to digest? How difficult would it be to deal with crumbs? These unknowns led state-run organizations, such as the United States' National Aeronautics and Space Administration (NASA) and the former Soviet Union's various groups (now Roscosmos) to provide early astronauts and cosmonauts (Russian astronauts) with pureed and cubed space foods. Yet although these foods made for fun gifts on Earth, they were not always so well received in outer space, and space food often returned to Earth uneaten (Perchonok & Bourland, 2002).

Astronauts' inadequate intake was problematic, not only because sending uneaten food to and from outer space was a waste of money, but also because it put astronauts at risk for nutrient deficiencies. Nutrient deficiencies have been shown to lead to impairments in mood, social skills, concentration, and ability to withstand stress (Keys, 1946; Keys, Brožek, Henschel, Mickelsen, & Taylor, 1950; Smith, Zwart, Kloeris, & Heer, 2009). Consequently, insufficient food intake posed a threat to astronauts' health and the success of space missions that depended upon their emotional, social, and cognitive abilities to respond in life-and-death situations.

**Advances in Space Food: Why Commercial Space Food Diets are Now Possible**

To overcome these difficulties with food intake, the United States government invested substantial resources into pioneering new food technologies that could pave the way to more palatable space foods (Hollender, 1969). First through the U.S. Army and the Air Force, and now through the NASA Space Food Laboratory, the United States developed numerous novel food technologies (Hollender, 1969). These new technologies were shared with American food manufacturers, resulting in many of the foods seen on grocery store shelves today. Portable, long shelf-life foods such as granola bars, heat-processed juice pouches, freeze-dried foods, and fruit bars are just a few of many types of foods that are commercially available, yet that can be traced back to technologies whose development was funded by the U.S. government (Marx de Salcedo, 2015). As a result of NASA, Army, and Air Force food endeavors, one can now purchase numerous foods from the supermarket that would work in outer space. This is good news for commercial aerospace companies SpaceX and Boeing, who are currently developing Crew[1] Transportation Vehicles under NASA contract. Starting in 2017, these Crew Transportation Vehicles could be used to transport NASA astronauts to and from the International Space Station (ISS). In the years after that, these vehicles could also be used to transport civilians to and from outer space, either to the ISS or to other, yet to be determined, locations.

Consequently, these commercial aerospace companies may want to provide food in their Crew Transportation Vehicles that could withstand flights to and from the ISS. This food would not be eaten on the ISS, but would be eaten on return trips after ISS stays, which are traditionally six months in duration. Accordingly, the food should have a minimum shelf life of seven months.

[1]The terms *crew* and *astronaut* will be used interchangeably throughout this manuscript.

To be usable on these flights, the food must be shelf stable and ready-to-eat, as refrigerators and food heaters would not be available. Additionally, the food should provide four days' worth of nutrition, as astronauts could be in the Crew Transportation Vehicle for up to this length of time.[2] The food must also be able to withstand the extreme conditions of spaceflight. As a result of the commercialization of NASA, Army, and Air Force technologies, numerous commercially available foods should now be able to meet these requirements; but can these foods keep astronauts nourished, satisfied with their diet, and both psychologically and physically healthy?

## Purpose, Aims, and Hypotheses

The purpose of this study was to evaluate the consequences of having an astronaut analog sample eat a diet of commercial, ready-to-eat food for four days (experimental condition / space food diet, designed by myself), as compared to eating as normal for four days (control condition). In particular, the specific aims of this study were to investigate the impact of the experimental condition on (a) nutrient intake, (b) food satisfaction, (c) psychological health, and (d) physical health. Although the study was health psychology-focused and therefore had the investigation of psychological health as its most critical aim, nutrient intake and food satisfaction greatly determine subsequent psychological health, and these two aspects will therefore be discussed first.

### Nutrient Intake

Astronauts require similar calories and nutrients in outer space as they do on ground (Kerwin & Seddon, 2002). NASA has set forth recommendations for the intake of calories (approximately 3,000 calories for an average active male) and other nutrients (see Table 1).

[2]Four days is approximately the maximum length of time astronauts would be in the Crew Transportation Vehicle.

Table 1 - Nutrient Requirements and Content of Space Food

| | ISS Nutrient Requirements[a] | Planned ISS Menu Content[a] | Experimental Diet Content[b] |
|---|---|---|---|
| Energy, kcal/d | Based on WHO[c] | 2877 ± 167 | 3040.56 |
| % of kcal from carbs | 50-55% | 50% ± 3% | 53.2% |
| % of kcal from protein | 12-15% | 17% ± 1% | 14.5% |
| % of kcal from fat | 30-35% | 31% ± 1% | 32.3% |
| % of kcal from saturated fat | -- | -- | 7.3% |
| Total fat, g/d | -- | -- | 109.99 |
| Total carbs, g/d | -- | -- | 407.62 |
| Total protein, g/d | -- | 126 ± 10 | 110.77 |
| Animal protein, g/d | 60% | 72 ± 7 | --[d] |
| Vegetable protein, g/d | 40% | 33 ± 3 | --[d] |
| Total fiber, g/d | 10-25 | 33 ± 4 | 35.96 |
| Vit A (retinol eq.) µg/d | 1000 | 1420 ± 205 | 627.52 |
| Vit C (ascorbic acid) mg/d | 100 | 191 ± 39 | 113.31 |
| Vitamin D, µg/d | 10 | 4.2 ± 1.0 | 3.25 |
| Vitamin E, mg/d | 20 | 12.1 ± 1.9 | 23.89 |
| Vitamin K, µg/d | 80 | 105 ± 19 | 24.47 |
| Thiamin (B1), mg/d | 1.5 | 2.0 ± 0.1 | 2.02 |
| Riboflavin (B2), mg/d | 2.0 | 2.2 ± 0.2 | 1.80 |
| Niacin (B3) equiv., mg/d | 20 | 29.8 ± 1.9 | 22.14 |
| Pantothenic acid (B5), mg/d | 5.0 | 5.1 ± 0.8 | 9.62 |
| Vitamin B6, mg/d | 2.0 | 2.3 ± 0.2 | 2.29 |
| Total folate (B9), µg/d | 400 | 434 ± 53 | 567.78 |
| Vitamin B12 µg/d | 2.0 | 4.6 ± 0.7 | 6.03 |
| Calcium, mg/d | 1000-1200 | 1020 ± 109 | 1283.51 |
| Phosphorus, mg/d | 1000-1200 | 1856 ± 165 | 793.98 |
| Phosphorus:calcium ratio | <1.5:1 | 1.83:1 ± 0.17 | 0.62:1 |
| Magnesium, mg/d | 350 | 424 ± 40 | 304.78 |
| Iron, mg/d | 10 | 22.7 ± 4.5 | 26.72 |
| Copper, mg/d | 1.5-3.0 | 3.6 ± 0.9 | 1.63 |
| Zinc, mg/d | 15 | 22.1 ± 6.2 | 10.02 |
| Manganese, mg/d | 2-5 | 5.7 ± 0.7 | 2.35 |
| Selenium, µg/d | 70 | 146 ± 16 | 34.14 |
| Iodine, mg/d | 0.15 | 1.0 ± 2.8 | .07 |
| Sodium, mg/d | <3500 | 5625 ± 531[e] | 2991.45 |
| Potassium, mg/d | 3500 | 3995 ± 360 | 838.27 |
| Water, g/d | 1mL/kcal, ≥2 liters / day | 2155 ± 206 | ~3 liters from food + drinking water |

[a]From Table 1 in Smith et al. (2009).

[b]From analysis of this study's experimental diet.

[c]World Health Organization energy requirements.

[d]NASA has a requirement for the percentage of protein from animal vs. vegetable sources. However, given that many of the ready-to-eat foods used in the experimental diet contained both animal and vegetable proteins and that I did not have access to a calorimeter, it was not possible for me to differentiate between animal and vegetable protein sources in the current study.

[e]ISS food has since been reformulated to achieve a sodium content of ~3300 mg/day (Douglas, 2014).

The four-day diet of commercial, ready-to-eat food that was used in this study (experimental diet) was designed by me to meet or nearly meet most all of the nutrient recommendations set forth by NASA (See Table 1, experimental diet content column).[3] This diet was also designed (and refined – see Preliminary Study below) to be highly satisfying and therefore desirable. Consequently, I hypothesized that *while in the experimental condition, participants would consume the same amount of calories as they did while in the control condition.* Moreover, I hypothesized there would be *no significant decline in caloric intake over the four days, as indicated by a non-significant time by interaction term.*

**Food Satisfaction**

Although the food in the experimental condition was designed to be highly satisfying, it was nevertheless a diet made entirely of commercial, ready-to-eat food. Consequently, I hypothesized that *while in the experimental condition, participants would rate the food as slightly more monotonous and slightly less hedonically rewarding, with "slightly" being defined as less than a two-point increase on the 9-point Food Monotony Scale* (Redden, 2013) *and less than a two-point decrease on the 9-point Hedonic Scale* (Jones, Peryam, & Thurstone, 1955; Peryam & Girardot, 1952). Despite these expected impairments, *I hypothesized the experimental condition food would, on average, still meet NASA's requirement of scoring 6.0 or higher on the Hedonic Scale (i.e., "like slightly" or better).* Although the experimental diet closely matches NASA's nutrient recommendations (Table 1), it nevertheless contains few vegetables and is a relatively sweet, salty diet. Consequently, I hypothesized that, *while in the experimental*

[3]For this four-day diet, some of NASA's nutrient requirements were more important than others. Inadequate calories, fat, protein, and sodium could impact psychological and physical health over the course of four days, whereas moderate Vitamin D or Vitamin K deficiencies would likely not. Consequently, the four-day experimental diet met all former requirements but "nearly met" some of the latter requirements, which were considered less critical for this short-term diet.

*condition, as compared to while in the control condition, participants would show higher cravings for vegetables and lower cravings for sweet, salty food* (Appetite Scale; Spiegel, Tasali, Penev, & Van Cauter, 2004). Finally, I hypothesized there would be *no significant decline in food satisfaction over the four days, as indicated by non-significant time by interaction terms.*

**Psychological Health**

During the experimental condition, participants were provided with a nutritious diet that had been designed to be highly satisfying and that was therefore expected to meet participants' psychological needs (see literature review of food satisfaction later in this manuscript). Consequently, I hypothesized that *while in the experimental condition, participants would show psychological health that was equivalent to their psychological health while in the control condition, as indicated by no significant differences in mood* (Brunel Mood Scale; Terry et al., 2003; Terry, Lane, Lane, & Keohane, 1999), *perceptions of social disconnection* (Feelings of Social Disconnection Scale; Eisenberger, Inagaki, Mashal, & Irwin, 2010)*, and perceived stress* (Perceived Stress Scale; Cohen, Kamarch, & Mermelstein, 1983). I also hypothesized there would be *no significant decline in psychological health over the four days, as indicated by non-significant time by interaction terms.*

**Physical Health**

Because the experimental condition food met the nutrient recommendations above, and because I hypothesized participants would consume equivalent calories in both the experimental and control conditions, I hypothesized that *while in the experimental condition, participants would have physical health that was equivalent to their health while in the control condition, as* *indicated by no significant weight loss and no significant differences in sleep* (Pittsburgh Sleep Quality Index; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) or *self-reported health* (General Self-Reported Health; WHO, 2007). I also hypothesized there would be *no significant decline in physical health over time, as indicated by non-significant time by interaction terms.*

## Literature Review

### Nutrient Intake

At the most basic level, astronauts require adequate nutrients from their food. Yet what is "adequate" for an astronaut? When human spaceflight first began, it was not clear what sort of calories and nutrients astronauts would require in microgravity.[4] During Project Mercury (1959-1963, up to 34-hour flights), which was the first NASA mission to send food to outer space, astronauts were provided with 2,500 calories a day (Altman & Talbot, 1987). This allotment was based on the assumption that astronauts would require fewer calories because floating in microgravity would require less use of their muscles (Altman & Fisher, 1986). Yet during these early flights, astronauts were losing weight (Stein et al., 1999). Caloric provisions were increased to 2,750 calories a day during Project Gemini (1965-1966, up to 330-hour flights), but still, astronauts were losing weight (Altman & Talbot, 1987). It wasn't until Project Apollo (1961-1975, up to 301-hour flights) and Skylab (1973-1974, up to 84-day flights) that it was realized the assumption astronauts required fewer calories was wrong. Human total energy expenditure while in microgravity was actually similar to that while on Earth (Lane et al., 1997), and

[4] *Microgravity* is a phenomenon that occurs during orbit. Spacecraft orbiting Earth are in free fall around the planet. Astronauts in these spacecraft therefore do experience gravity, as they are also in free fall, but because they fall at the same rate as the spacecraft, gravity feels nonexistent. The terms microgravity, zero gravity, and weightlessness are often used interchangeably, but in this manuscript the term microgravity will predominantly be used.

astronauts therefore needed as many calories in outer space as they did on ground: approximately 3,000 calories a day for an active male (Altman & Talbot, 1987; Smith et al., 2009).

However, a diet of 3,000 calories can come from many sources. What food sources should be included in an astronaut's diet? This was a major point of investigation on Skylab. During Skylab flights, NASA conducted the most extensive studies of nutrient metabolism in outer space to date (Altman & Fisher, 1986; Perchonok & Bourland, 2002). Astronauts recorded all the food they ate, collected biological samples, and underwent numerous nutritional experiments. For three weeks before and after Skylab flights, astronauts also ate the same food that they would have eaten during flight, so that researchers could investigate how spaceflight – rather than the space food – altered metabolism (Altman & Fisher, 1986). Data from these and other studies showed astronauts experienced various physiological changes that slightly altered their needs for a few micronutrients (i.e., vitamins and minerals). Yet for the most part, astronauts' nutrient needs remained the same, and they needed just as many calories in space as they did on ground. Astronauts therefore required essentially typical diets (Matsumoto et al., 2011; Smith et al., 2009). NASA's current nutrient requirements are shown in Table 1.

However, even when astronauts were provided with sufficient nutrients, they often did not consume sufficient amounts. Historically, astronauts have consumed far fewer calories than were provided to them (Altman & Talbot, 1987). It was only during the Skylab missions that astronauts consumed their recommended caloric intake, and this was likely because Skylab had many things that missions before and since have not had: a dining room table, a refrigerator, a freezer that contained ice cream and steak, and extensive studies that required astronauts eat certain foods (Kerwin & Seddon, 2002; NASA, 2002).

Astronauts' food intake since Skylab has failed to meet NASA's requirements, despite NASA providing sufficient food on Space Shuttle flights (1981-2011, up to 17-day flights) and on stays at the International Space Station (2000-present, up to one-year flights; Smith et al., 2009). On the Space Shuttle, astronauts ate about 1995 calories a day (Lane, Smith, Rice, & Bourland, 1994). Currently, ISS astronauts self-report eating about 80% of their recommended caloric intake (as reported on the ISS-adapted Food Frequency Questionnaire; NASA, 2002; Smith, Zwart, Block, Rice, & Davis-Street, 2005). NASA can encourage astronauts to eat more food, but ISS astronauts live hundreds of miles away from NASA's headquarters, and consequently astronauts can eat what they please. The amount that astronauts eat is often less than what NASA would prefer. There are likely many reasons for this undereating, but one historical factor has been low food satisfaction.

**Food Satisfaction**

*Food satisfaction* is multifaceted, but three aspects of food satisfaction that became apparent to NASA early on, and which will therefore be used as operational definitions of food satisfaction in this study, were acceptability, familiarity, and variety (Bourland, 1993). *Acceptability* refers to the extent to which a food is hedonically pleasing. In other words, how much does one "like" the food? Highly acceptable foods are highly palatable and lead to increased food intake (de Graaf et al., 1999; reviewed by Sørensen, Møller, Flint, Martens, & Raben, 2003), whereas foods that have low acceptability lead to decreased food intake (Yeomans, 1996). NASA evaluates the acceptability of food items prior to flight via on-ground taste tests, during which time future astronauts taste food items and rate them on the 9-point Hedonic Scale (Peryam & Girardot, 1952). The Hedonic Scale asks participants to rate a food item from “dislike extremely” to “like extremely.” Items rated as a 6.0 (“like slightly”) or higher are deemed “acceptable" by NASA and can be considered for use in flight (Weiss, 1969).

*Familiarity* refers to the extent to which a food item looks, feels, tastes, and otherwise resembles food one has eaten on a regular basis (Tuorila, Meiselman, Bell, Cardello, & Johnson, 1994). For example, steak with a side of vegetables is familiar, whereas a tube of pureed beef and vegetables is not. Sugar cookies are familiar, whereas sugar cookies compressed into cubes and coated with gelatin to prevent crumbling are not (Bourland, 1993). Both “Pureed Beef and Vegetables” and “Sugar Cookie Cubes” are former space foods. Although these foods may have started with familiar ingredients, the final form of the food had unfamiliar textures and “mouthfeels” (Bourland, 1993) and consequently these foods had low familiarity. Astronauts prefer to eat foods that are familiar and tend to eat less of foods that are unfamiliar (Bourland, 1993).

*Variety* refers to the extent to which there is variation in a diet. A diet with insufficient variety is monotonous, and a diet that is monotonous leads, in time, to decreased acceptability and decreased food intake. Researchers have found through laboratory studies that eating the same food for five days in a row decreases acceptance ratings and intake of that food (Meiselman, de Graaf, & Lesher, 2000). People prefer variety in their diet and eat more food when presented with various food options (reviewed by Sørensen et al., 2003).

When NASA was first producing food for Projects Mercury and Gemini, the importance of variety and familiarity were not yet fully known. However, it was obvious to NASA that the food must be nutritious and acceptable. NASA therefore made sure to provide nutrition-filled foods that were rated acceptably in on-ground taste tests. Nevertheless, in an effort to reduce the weight, volume, and messiness of the food, NASA food scientists put the foods into pureed and cubed form, and consequently the familiarity and variety of the foods was decreased. As a result, astronauts did not consume sufficient calories during flight (Bourland, 1993).

To alleviate the problem of undereating, NASA overhauled the food system during the Apollo program and started to provide astronauts with fewer tubed and cubed foods and more dehydrated, irradiated, and thermostabilizd (i.e., heat-treated) foods (Bourland, 1993; Perchonok & Bourland, 2002). These treatments prolonged food shelf life while also providing more acceptability, variety, and familiarity in the diet. Some of these foods could even be eaten with a spoon, much like how food is eaten on ground (Perchonok & Bourland, 2002). NASA has continued to strive for increases in the acceptability, variety, and familiarity of space food, and as a result, astronauts' satisfaction with space food has increased. However, food intake remains below goal and there continues to be room for improvement.

**Psychological Health**

Spaceflight involves numerous stressors and challenges to psychological health. For instance, astronauts are separated from their families by hundreds of miles, living in a confined, isolated environment with colleagues for months on end – and they don't always get along. As evidence, ISS astronauts kept journals as part of a study that ran from 2003 until 2016, and these journals reveal crewmembers can, at times, be inconsiderate and bothersome, and occasionally even argumentative. As one astronaut wrote, "I was really livid after Z snapped at me quite viciously about something that wasn't my fault. I let Z have it, like I can't remember ever before in a professional relationship, and stormed off" (Stuster, 2010, p. 22). Another stressor is that astronauts are provided with strict schedules by Mission Control, leading to numerous daily hassles (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982) such as not having enough time to get everything done. As one astronaut wrote in a journal, “Today was a hard day. Small things are getting to me. I am tired. I think that the ground is scheduling less time for tasks than before. So, there is very little, if any fat left in the schedule for me to use to catch up on little things during the day” (Stuster, 2010, p. 10). Difficulties with sleep, personal hygiene, and expectations from both oneself and others are also stressors. These stressors can impair morale and psychological health (Stuster, 2010).

However, morale and psychological health can be improved with satisfying food, as has been shown in on-ground and in-flight studies (Perchonok & Bourland, 2002). On-ground, in laboratory studies, researchers have found that eating a well-liked food improves mood, whereas eating less-liked food does not (Hill, Magson, & Blundell, 1984). In space, astronauts on both Skylab and the ISS have reported the importance of food in improving mood, decreasing stress, and promoting feelings of social connection. For instance, the Skylab 2 crew recounted fond memories of smothering ice cream with strawberry sauce and eating together as they watched Earth out the window (Kerwin & Seddon, 2002). ISS astronauts’ journals also reveal the importance of food in improving mood and stress: “Almost supper time! It’s amazing how meals become the high points of the day sometimes” (p. 36), “The good news is that we have good food on board now. It makes such a huge difference in mental attitude” (p. 35; Stuster, 2010). Astronauts’ journals also show how food can impact social connectedness: “We had a great dinner last night. Even X took a break from packing to enjoy the company and camaraderie. It was a testament to the unique bonds we all have from sharing the experience” (p. 36), “We ate together and talked and laughed. It was a good day for our crew” (p. 36; Stuster, 2010).

Satisfying food can clearly benefit psychological health. Yet disappointment with the acceptability, variety, and familiarity of food can also lead to psychological problems, as shown in other ISS astronaut journal entries: “The food is getting somewhat old to us . . . it is starting to all look and taste the same” (p. 35), “Last week was difficult and long. Probably seemed like it, because of the food situation” (p. 17), “Food is still our biggest concern. We are out of side dishes, such as potatoes and vegetables” (p. 35; Stuster, 2010).

As these entries show, dissatisfaction with food can lead directly to psychological difficulties, such as frustration and stress. Yet dissatisfaction with food can also lead to psychological problems through the mechanism of undereating. People eat less of food that is not sufficiently satisfying (de Graaf et al., 1999; reviewed by Sørensen et al., 2003), and if food intake is inadequate for an extended period of time, it can lead to severe psychological consequences. In Ancel Keys’ Minnesota Starvation Experiment (1944-1945), where 36 men ate approximately 1,560 calories for six months, participants experienced numerous psychological problems, including moodiness, depression, irritability, social withdrawal, and preoccupation with food (Keys, 1946; Keys et al., 1950). Restricting caloric intake has also been shown to increase salivary cortisol, a biological indicator of stress (Tomiyama et al., 2010). Even having to monitor one’s diet can lead to increased perceived stress (Tomiyama, et al., 2010), and food monitoring is something that astronauts routinely engage in when they audit their food stocks, when they ration their food supplies, and when they complete their weekly Food Frequency Questionnaire (Smith & Zwart, 2008).

Psychological harm resulting from un-satisfying food or insufficient food intake is particularly worrisome when it comes to spaceflight because emotional stability, social skills (e.g., teamwork, ability to cohabitate, communication), and ability to work under extreme stress are important human factors in the success of space missions (Musson, Sandal, & Helmreich, 2004; Slack, Holland, & Sipes, 2014). NASA carefully selects astronauts to have these and other personality traits that will enable them to excel in the isolating, confined, and hazardous conditions of outer space (Musson et al., 2004). Yet no matter how carefully selected, astronauts do experience psychological problems. During flight, astronauts can experience irritability, anxiety, loneliness, superiority complexes, low morale, and difficulties concentrating (Perchonok & Bourland, 2002), which can impair astronauts' ability to carry out missions. For instance, during the Skylab 4 and Apollo 13 flights, irritability and interpersonal conflict among crewmembers and between crew and ground controllers became so intense that the crew took time off of work to resolve difficulties (Collins, 1985; Kanas, 1987).

Given that astronauts can experience psychological problems during flight, and given the research showing that insufficient food intake and unsatisfying food can contribute to psychological problems, whereas satisfying food can contribute to psychological health, the importance of providing astronauts with a satisfying diet is clear. However, aiming to provide foods that benefit psychological health and actually doing so are two very different things. NASA has long aimed to use food as a mood booster through providing food that looks and tastes "home cooked" (Bustead & Tuony, 1966). Yet as mentioned earlier, the food fell short in many ways. Consequently, when designing new space food diets, it is important to assess the food's actual impact on psychological health. Given that emotional stability, teamwork, and ability to work under extreme stress are among the most important factors in the success of space missions (Musson et al., 2004; Slack et al., 2014), it is especially important to assess the impact of new space food diets on mood, social connection, and perceived stress.

## Physical Health

Dissatisfaction with food can lead to decreased food intake (de Graaf et al., 1999; reviewed by Sørensen et al., 2003), and inadequate food intake can result in numerous harms to physical health. Three harms that are particularly concerning when it comes to astronauts are weight loss, sleep difficulties, and poor self-reported health.

*Weight loss* in astronauts is both common and dangerous. When humans lose weight, either in outer space or on Earth, this weight is in the form of both lean body mass (e.g., "muscle") and fat mass (i.e., "fat"). In non-astronaut populations, the goal of weight loss is usually to lose more fat mass than lean body mass. Indeed, when healthy, ambulatory humans lose weight on Earth, most of this weight is in the form of fat mass, with a lesser percentage of the lost weight coming from lean body mass (de Souza et al., 2012; Gallagher et al., 2000). However, when humans are not ambulatory, as is the case with astronauts during transport, a larger percentage of the lost weight can come from lean body mass. In one crossover study – a type of study in which the same participants are exposed to all conditions – Biolo and colleagues (2007) tested the consequences of a weight-loss diet versus a weight-maintenance diet during either ambulatory or non-ambulatory (bed rest) conditions. When participants were on the weight-loss diet and ambulatory, most of their weight loss was in the form of lost fat mass (mean loss = 1kg) rather than lean body mass (mean loss = 0.3kg). However, when participants were on the weight-loss diet and bed rest, their weight loss was in the form of similar amounts of lost fat mass (mean loss = 1kg) and lean body mass (mean loss = 1.1kg). In other words, weight loss coupled with inactivity leads to greater loss of lean body mass.

The loss of lean body mass is already a phenomenon that occurs in human and non-human animals living in microgravity (Fitts, Riley, & Widrick, 2000). Therefore, weight loss could exacerbate this loss of lean body mass in astronauts, which could lead to the loss of muscle volume and the loss of bone mineral content (LeBlank et al., 2000). These outcomes could lead to increased risk for soft tissue injury (e.g., a sprain), bone fracture, and decreased stamina (Matsumoto et al., 2011), which could increase astronauts' risk of being injured during extravehicular activities and of having difficulty readjusting to gravity on Earth or other planets. In summary, when astronauts are in a microgravity environment, and especially when they are physically inactive, such as they will be in the Crew Transportation Vehicle, weight loss could result in the loss of lean body mass. Consequently, assessing the impact of space food on weight loss will be important.

*Sleep difficulties* are also common in astronauts. Astronauts sleep significantly less during ISS missions, as compared to after, and 75% of ISS crewmembers report using medications to promote sleep (Barger et al., 2014). The most frequently used sleep medication during spaceflight is zolpidem (brand name Ambien), a medication with side effects that can include difficulty with balance, unusual dreams, headache, gastrointestinal problems, and feeling "drugged" (U.S. National Library of Medicine, 2015). Despite the common use of this and other sleep-promoting medications among astronauts, and despite a NASA mandate that astronauts have 8.5 hours for sleep per night, ISS astronauts average only 6.09 hours of sleep a night (Barger et al., 2014). Sleeping 6 to 6.9 hours a night was shown in one epidemiological study of over 175,000 people to significantly increase the risk for work-related injury (Lombardi, Folkard, Willetts, & Smith, 2010).

Sleep deprivation has also been linked to psychological impairments such as negatively biased mood, difficulty using one's emotions to make decisions, impaired frustration tolerance, and reduced attention, vigilance, and memory (Killgore, 2010; Pilcher & Huffcut, 1996). Even when alertness is restored with stimulants such as caffeine, many of these impairments remain (Killgore, 2010). Astronauts have access to coffee, caffeine pills, and stimulant pills, such as modafinil (brand name Provigil; Whitmire et al., 2013). Yet their journals still report numerous instances of sleep deprivation leading to impaired functioning, such as "I fell asleep while typing" (p. 32) and "The fatigue was evident when a couple of minor mistakes were made today on some payload activities . . . it is an obvious indicator of fatigue" (p. 13; Stuster, 2010). Astronauts' sleep deprivation could pose a serious threat to both themselves and to the success of space missions (Mallis & DeRoshia, 2005). Factors that can exacerbate sleep difficulties should therefore be avoided (Mallis & DeRoshia, 2005).

Food is one such factor that could exacerbate sleep difficulties. In a nationally representative study of 5,587 U.S. adults, eating a reduced-variety diet, consuming less salt, and consuming a low number of calories was associated with self-reports of sleeping less than five hours a night, as compared to self-reports of sleeping 7 to 8 hours a night (Grandner, Jackson, Gerstner, & Knutson, 2013). The researchers also found significant associations between sleep duration and the intake of numerous nutrients, including intake of carbohydrates, proteins, vitamins, and minerals (Grandner et al., 2013). In summary, aspects of food intake have been associated with impaired sleep, and because astronauts already have sleep difficulties, it is important to evaluate how new space food diets impact sleep.

Unlike sleep difficulties and weight loss, poor *self-reported health* is not often emphasized by NASA as a potential health risk. However, asking participants to rate their own health as excellent, very good, good, fair, or poor is well recognized in health fields as a robust, reliable, and valid way to assess overall health status (Bowling, 2005; Statistics Canada, 2015). Self-reported health, also called self-rated health or perceived health, predicts functional ability (Idler & Kasl, 1995) and mortality (Idler & Benyamini, 1997). Self-reported health predicts mortality even after controlling for numerous potential confounds such as age, sex, income, education, and health practices (Kaplan & Camacho, 1983). Asking participants to rate their own health is a robust predictor of health outcomes, even when the wording of the question varies (Idler & Benyamini, 1997; Shields & Shooshtari, 2001).

Self-reported health is usually used as an indicator of health over long time periods, but researchers have found that participants' ratings can also change over relatively short periods of time, indicating that self-reported health could be used as a marker of short-term changes in health.  For instance, when 9,235 participants in the 2005-2008 National Health and Nutrition Examination Survey (NHANES) were surveyed at two time points one month apart, nearly 40% of participants changed their response to the question, "In general, would you say your health is excellent, very good, good, fair, or poor?" (Zajocova & Dowd, 2011). Additionally, when a variant of the self-reported health question, "Overall, how satisfied were you with your health today?" was used in a 56-day survey study, researchers found significant day-to-day, within-person variability (Whitehead & Bergman, 2013). Greater day-to-day health satisfaction was also associated with fewer health events (Whitehead & Bergman, 2013). Consequently, although self-reported health is traditionally used as an indicator of health over long time periods, it can likely also be used to assess variation in self-reported health over days or weeks. Self-reported health could therefore be used to assess how new space food diets impact health over time.

## Preliminary Study

A preliminary study was conducted to select the experimental diet and to select the measures used to assess nutrient intake, food satisfaction, psychological health, and physical health.

### Selecting the Diet

I first retrieved NASA's nutrient requirements for ISS missions (Table 1) and entered these requirements into a nutrition analysis program (The Food Processor from ESHA Research) as a target for the diet. The Food Processor uses USDA databases, allows for the entry of new food items, and allows for the creation and analysis of multi-day and multi-person diets, making it ideal for use in this study.

I then searched for foods that would be acceptable, varied, and capable of being eaten in outer space (e.g., low-weight, no crumbs, sufficient viscosity not to float away). Ideas for these foods came from the following sources: lists of NASA-flown foods, lists of commercial food items that astronauts have been allowed as "bonus" foods during flight, websites that sell survival food and camping food, prior space food proposals from commercial aerospace employees, and NASA feedback on those prior food proposals. Foods that have historically been favorites of astronauts were also taken into account, such as tortillas (loved by astronauts because they are easy to eat and can be combined with numerous foods) and shrimp cocktail (a favorite of astronauts because it is spicy and spaceflight, for numerous reasons, seems to dull astronauts' sense of taste; Stuster, 2010; Lane, Kloeris, Perchonok, Zwart, & Smith, 2006).

After reviewing all these sources, I generated a list of commercial, ready-to-eat foods that could be considered for inclusion in the diet. For instance, I could not locate individually wrapped, long shelf-life tortillas on the commercial market, but I was able to locate some shelf stable, individually wrapped breads and sandwiches. I also could not locate shelf stable shrimp cocktail on the commercial market, but I was able to locate other spicy, shelf stable entrées. After generating this list, I went to grocery stores online and in person and purchased the items. I also purchased foods that were not on my list but that looked like viable options, such as some shelf stable, pouched yogurts that had recently come on the market.

With the food in hand, I then evaluated the mass and volume of the packaging. I discarded foods that had heavy or excessive packaging and those that had packaging containing unnecessary volume in the form of unused airspace. I also evaluated the crumbliness, viscosity, and taste of the food. After this process, I had a collection of food that was low in mass and volume, non-crumbly and viscous (so as not to float away in microgravity), and appetizing enough to be considered for flight (based on personal opinion). I then tracked down the shelf life of each item – online, by email, or by phone – and eliminated any food with a shelf life of less than 11 months, so as to provide ample time for attaining and preparing food prior to flight.

Next, I collected images of the remaining items and used these images to visually approximate acceptable, varied meals. Familiarity was less of a concern during this process because I was starting with foods that could be purchased at grocery stores and which were therefore already somewhat familiar. I then conducted taste tests with commercial aerospace engineers to gain insight into how the acceptability and variety of the diet could be further increased. Engineers tasted various dishes and provided quantitative and qualitative feedback. Based on their feedback, I designed a four-day diet. I entered this diet into The Food Processor and tweaked the diet until it closely matched NASA's nutrient requirements and provided approximately 3,000 calories per day. This caloric target was chosen so as to provide both male and female participants with sufficient calories. At the end of this process, I had designed the final experimental diet, shown in Table 2.

Table 2 – Experimental Diet Food Items

| | **Day 1** | **Day 2** | **Day 3** | **Day 4** |
|---|---|---|---|---|
| **Breakfast** | French Toast<br>Pureed Spiced Fruit<br>Cookie Dough Snack Bar | Cherry Turnover<br>Blueberry Yogurt Bar<br>Berry Yogurt | Berry Meal Bar<br>Peanut Butter Protein Bar<br>Pineapple Applesauce | Lemon Snack Bar<br>2.15oz Turkey Jerky+Fruit+Nuts<br>Berry Applesauce<br>Nut Butter Protein Bar |
| **Lunch** | Bison and Fruit Bar<br>Kung Pao Noodle Entrée<br>Berry Energy Chews | Punjab Potato Entrée<br>Chocolate Coconut Meal Bar<br>Bacon Bar | Peanut Noodle Entrée<br>Cacao Banana Protein Bar<br>Strawberry Yogurt | Blueberry Turnover<br>Oatmeal Raisin Energy Bar<br>Vanilla Pudding<br>Strawberry Kiwi Energy Gel |
| **Dinner** | BBQ Chicken Sandwich<br>Chocolate Pudding<br>4oz Beef Jerky+Fruit+Nuts | Italian-Style Sandwich<br>BBQ Sauce<br>2.15oz Turkey Jerky+Fruit+Nuts<br>Honey Mustard Nut Bar<br>Almond Brownie Snack Bar | BBQ Beef Sandwich<br>BBQ Sauce<br>Strawberry Energy Chews<br>2.15oz Beef Jerky+Fruit+Nuts<br>PB Chocolate Snack Bar | Italian-Style Sandwich<br>Spicy Beef and Cherry Bar<br>Hickory Smoked Nut Bar<br>Strawberry Meal Bar |
| **Snack** | PB Chocolate Chip Meal Bar<br>Carrot Cake Bar | Chocolate Energy Bar<br>Cran-Razz Energy Chews<br>Peanut Butter Cookie Snack Bar | Trail Mix Bar<br>Vanilla Almond Bar | Blueberry Vanilla Cashew Bar<br>Citrus Energy Chews |

## Selecting Measures

**Nutrient intake.** This study was health psychology-focused and therefore only caloric intake, a strong predictor of psychological and physical health outcomes (Biolo et al., 2007; Tomiyama et al., 2010), was used as a measure of nutrient intake. Data on fluid intake was gathered but, because commercial astronauts will be provided with sufficient drinking water independent of the food they receive, fluid intake was not included in the planned analyses.

**Food satisfaction.** The literature review revealed that three important factors in food satisfaction are acceptability, variety, and familiarity. To assess acceptability, participants completed the same 9-point Hedonic Scale that is completed by NASA astronauts in on-ground taste tests (Peryam & Girardot, 1952; Weiss, 1969). Participants completed this 9-point Hedonic Scale for every item that they ate. To assess variety, participants completed a measure of perceived diet monotony that had been used in previous NASA-funded research (Redden, 2013). All of the items included in the experimental diet were highly familiar, in that they could all be purchased at local grocery stores, unlike many NASA space foods. Consequently, the familiarity of the diet was not assessed. Instead, food cravings were assessed using the Appetite Scale (Spiegel et al., 2004) so that this study could shed light on ways to improve the experimental diet by adjusting it to meet participants' food cravings.

**Psychological health.** The literature review revealed that emotional stability, teamwork, and ability to work under extreme stress are among the most important psychological factors in the success of space missions (Musson et al., 2004; Slack et al., 2014). These are three factors that could also be impacted by diet (Keys, 1946; Keys et al., 1950; Tomiyama et al., 2010). Consequently, in this study, psychological health was assessed via mood (Brunel Mood Scale;

Terry et al., 1999; Terry et al., 2003), social disconnection (Feelings of Social Disconnection Scale; Eisenberger et al., 2010), and stress (Perceived Stress Scale; Cohen et al., 1983).

**Physical health.** The literature review also revealed that unsatisfying food and inadequate food intake contribute to numerous physical problems, and that three physical health outcomes were particularly important to investigate in astronaut studies: weight loss, sleep difficulties, and self-reported health. Consequently, in this study, physical health was assessed via weight change, sleep difficulties (Pittsburg Sleep Quality Index; Buysse et al., 1989), and self-reported health (General Self-Reported Health; WHO, 2007).

## Methods

### Participants

To maximize my ability to generalize the results to astronauts who have high workloads, I sampled participants from the high-workload pool of individuals at a local commercial aerospace company (SpaceX). Employees at this company tend to be space enthusiasts, and thus they may also be likely to purchase commercial spaceflights, once they become readily available. Participants (target N = 6, at least 20% female; final N = 7, 57% female) were recruited via email using non-random convenience sampling. The email directed individuals who were interested in participating to complete a Work-Specific Food Survey (Appendix A). This survey asked individuals if they met the eligibility requirements (see Eligibility Requirements section below) and several questions about their typical eating habits at work. The survey also asked individuals if they were able to eat the experimental food, if they were “picky” eaters, and if they avoided certain food groups. Individuals were asked to respond to these questions with “yes,” “maybe,” or “no” answers. Individuals who were eligible for the study and who definitively (e.g., “yes” or “no”) confirmed that they were able to eat the experimental food, were not picky eaters, and did not avoid food groups were considered for participation in the study. The Work-Specific Food Survey also asked individuals how often they ate the food that was served at work. Individuals who regularly ate the food served at work were preferred for participation over individuals who did not regularly eat the food served at work.

**Timing**

To ensure participants would have sufficient time to devote to the study, the study was conducted in May 2016. This was a month that was relatively free of major Crew Transportation Vehicle development deadlines.

**Consent**

When participants expressed interest in participating, I met with them for a one-on-one meeting at their workplace in a private area. During the meeting, I provide them with a list of eligibility requirements, a description of the study, and a consent form. Participants were provided with up to one day to think over the study before they provided their consent and confirmed that they were or were not eligible for the study. Once participants provided consent, I also obtained consent from their managers to ensure the study would not conflict with any time-sensitive projects. This was done by having participants forward their managers an email that I had written. The email explained the goals of the study, what study participation entailed, and the time burden of the study. Employees were only allowed to participate in the study once they forwarded me an email from their manager providing approval. All managers provided approval.

## Eligibility Requirements

To ensure participants were representative of future commercial astronauts, all participants had to express an interest in traveling to outer space. Participants also had to be willing and able to eat breakfast, lunch, and dinner at work Monday through Thursday for two weeks. Additionally, participants had to be willing and able to eat only the food provided during the experimental condition and to eat from a restricted number of food venues at the workplace during the control condition. These eligibility requirements were anticipated to increase study adherence. Participants also had to report no endocrine or metabolic disorder, as eating the processed, ready-to-eat food could have exacerbated these disorders. Finally, participants had to report no current dieting and no history of an eating disorder, as these factors could have adversely impacted participants' eating or rating of the foods.

## Protecting Participants' Identities

Each participant was asked to make up a participant code. These codes were used to track participants' data throughout the study. Participants' phone numbers were collected and used as part of the study (to send participants reminders to complete the surveys), but their phone numbers were not connected with their participant codes or their data.

## Compensation

Participants were compensated in the form of free food. During the experimental condition, this consisted of commercial, ready-to-eat food provided in a tote bag, which was valued at around $200 per person. During the control condition, participants were given 16 vouchers for food, each worth $5, which was the maximum cost of any meal at the workplace. Participants' total compensation was therefore estimated to be $280 for the duration of the study.

**Procedure**

UCLA Institutional Review Board approval was obtained prior to conducting study procedures. The study was then run during the workweek so as to provide a high-workload environment. A parallel crossover design was used over the course of two weeks. The parallel crossover design was selected because this type of design achieves greater statistical power and precision with fewer participants, as compared to a parallel design (Wellek & Blettner, 2012), and recruiting participants from the pool of commercial aerospace employees was anticipated to be difficult. For the parallel crossover design to be most effective, a "washout" period between conditions is required (Wellek & Blettner, 2012). Therefore, this study involved food manipulation Monday through Thursday with a three-day "washout" period Friday through Sunday. During this washout period, participants ate as normal without recording their food intake.

During week 1, half the participants were randomly assigned to the experimental condition, while the other half were in the control condition. During week 2, this arrangement flipped, with the participants who were previously in the experimental condition switching to the control condition, and vice versa. Both the experimental and control conditions lasted 4 days in Week 1 (Monday through Thursday) and 4 days in Week 2 (Monday through Thursday). All participants completed the study during the same two-week period. The procedure is shown in Table 3. Each week of the study required approximately 107 minutes of the participant's time. Participants also completed a brief qualitative assessment at the very end of the study, which took approximately 10 minutes. This brought a participant's total time commitment to 224 minutes, or approximately 3.75 hours, for the entire study.

Table 3 – Study Procedure Weeks 1 and 2

| | Monday | t | Tuesday | t | Wednesday | t | Thursday | t | Friday | t |
|---|---|---|---|---|---|---|---|---|---|---|
| Before Break-fast | Weighed<br>Get supplies | 1<br>3 | Drop off Log<br>Drop off Leftovers | -<br>1 | Drop off Log<br>Drop off Leftovers | -<br>1 | Drop off Log<br>Drop off Leftovers | -<br>1 | Weighed<br>Drop off Log<br>Drop Leftovers<br>Post Survey | 1<br>-<br>1<br>6 |
| After Break-fast | Food Log | 3 | Food Log | 3 | Food Log | 3 | Food Log | 3 | | |
| After Lunch | Food Log | 3 | Food Log | 3 | Food Log | 3 | Food Log | 3 | | |
| Evening | Evening Survey | 11 | Evening Survey | 11 | Evening Survey | 11 | Evening Survey | 11 | | |
| After Dinner | Food Log | 3 | Food Log | 3 | Food Log | 3 | Food Log | 3 | | |
| After Snack | Food Log | 3 | Food Log | 3 | Food Log | 3 | Food Log | 3 | | |
| Daily Time | | 27 | | 24 | | 24 | | 24 | | 8 |

t = estimated time commitment in minutes

Evening Survey: Food Monotony (1 minute), Food Cravings (2 minutes), Mood (5 minutes), Self-Reported Health (1 minute), Social Disconnection (1 minute), Perceived Stress (1 minute)

Post Survey: Sleep Difficulties (5 minutes), Ten Item Personality Inventory (1 minute)

**Procedure for both conditions.** Regardless of the condition to which they were assigned, participants met me in a workplace conference room between 8:00am and 10:00am on Monday morning. At that time, they received their condition instructions (explained further below, also shown in full in Appendix B), along with a bullet-point list of foods they could and could not week eat that week. All participants were reminded they would be weighed right then (Monday morning) and on Friday morning, before eating. They were also reminded they would receive an email with a link to an online survey at 5:00pm on Monday, Tuesday, Wednesday, and Thursday of both weeks. Finally, all participants were told they would receive text message reminders to complete the survey at 6:00pm and 7:00pm each night, and they were expected to complete the survey before 8:00pm. Participants were asked to complete the survey on a computer, rather than on a smartphone, so that all questions would display in correct formatting.

The timeframe of 5:00 to 8:00pm was chosen for the evening survey because participants often remained at work until 7:00pm or later, and I expected participants would be more likely to complete the survey if they completed it before leaving work. However, data were not discarded for being submitted after 8:00pm.

**Procedure for experimental condition.** When participants met me on Monday morning, they received their tote of experimental condition food. The tote included four gallon-sized plastic bags, with each bag containing one day's worth of food. The bags were labeled Day 1, Day 2, Day 3, and Day 4. Each gallon-sized bag contained four smaller plastic bags in which the food was actually stored. These bags were labeled Breakfast, Lunch, Dinner, and Snack. Participants were also provided with a binder that showed the breakfast, lunch, dinner, and snack options that were provided for each day. Participants were informed that the meal categories were recommendations only and that they could eat anything from the tote at any time.

Because the food was designed to be lightweight and portable, participants were able to carry the tote with them everywhere they went. All totes contained the same exact food (see Table 2 for a list of all the food items). This food was designed to provide sufficient calories for all participants. All totes also included eight empty two-gallon-sized plastic zip bags for storing leftover food. When participants picked up their totes, they were also provided with a stack of Food Rating Logs (Appendix C) and the experimental condition instructions, shown below:

*This Monday, Tuesday, Wednesday, and Thursday, you are to eat breakfast, lunch, and dinner at work. You will only eat the food from this tote bag, and no other food. You may eat snacks at home or out-and-about after work, but these snacks must come from the food provided here.*

*This tote bag contains 4 bags of food labeled Day 1, Day 2, Day 3, and Day 4. Bring this tote bag with you anywhere you may want to eat (e.g., to home and back to work). You may pick and choose what to eat from any of the four bags, at any time of the day. However, you are encouraged to eat from only one bag per day, so that you will have sufficient food to eat on all four days.*

*Eat only what you want from the food provided. You do not need to eat all the food.*

*You are, however, strongly encouraged to try every type of food in your tote bag. The foods in your tote have been taste tested by SpaceX employees and were rated as very tasty. I* *expect that you will find the food, even the food that may be unfamiliar to you (such as the sandwiches) to be very tasty.*

*Eat your meals and snacks at the time you would normally eat, in the places where you would normally eat, and with the people with whom you would normally eat. For example, if you normally eat lunch at 12:00pm with your colleagues on the Mezz, keep doing that. However, do not let anyone else eat any of your food, as that would throw off my measurements! If someone asks to have a bite of your food, tell them "no," as your food intake is being assessed as part of this study. If they really want to try the food (as I assure you, it is tasty), you can refer them to me and I will give them a sample.*

*For the next four days, after you eat or drink ANYTHING, write what that food or drink is on the Food Rating Log for that day (the Food Rating Logs are behind this sheet). Please take a look at the Food Rating Log now, and then come back to this instruction sheet.*

*On the Food Rating Log, for Amount, you can write down "1" if you eat the whole package of food, "1/2" if you only ate half of it, or "1 bite" if you took one bite and didn't finish the rest. Rate each item that you eat (even if you only ate part of it) using the 1 ("dislike extremely") to 9 ("like extremely") scale that is shown on the Food Rating Log.*

*You can drink water, tea, and black coffee (no soda, and no cream or sugar in any drinks), but be sure to write down every time you drink and how much you drank (e.g., 12oz coffee, 20oz water) on the Food Rating Log, as you would write down food. You do NOT need to rate your drinks using the 1 to 9 scale.*

*This tote bag also contains eight empty two-gallon-sized Ziploc bags. Each time you eat something, put all your leftovers – both leftover food and packaging – in the bag for that day.*

*Tuesday, Wednesday, Thursday, and Friday morning between 8:00am and 10:00am, bring your previous day's Food Rating Log and your previous day's bag of leftovers to me. On Friday morning, you will also hand over all remaining food. If you run out of food before Friday, just let me know and I will provide you with more food.*

As the instructions explained, if a participant ran out of food, they could obtain additional food items. Participants were able to request particular food items, but they could only request items from the list of foods that had been included in their experimental condition tote. Running out of food was not anticipated, as 3,000 calories was expected to be sufficient for all employees. Nevertheless, if an astronaut were to run out of food during flight, that astronaut would likely be able to take food from someone else's supply. Consequently, participants in this study were allowed to obtain as much food as they needed.

**Procedure for control condition.** When participants met me on Monday morning, they received vouchers for four days of meals at work, the control condition instructions (Appendix B), and four Food Rating Logs (Appendix C). The control condition instructions outlined that, for the next four days, they would be allowed to eat from the workplace food outlets that served restaurant-style, pre-determined portions (as opposed to self-serve outlets). This provided participants with approximately 12 meal options at any time of the day. Participants were not allowed to eat from the cafeteria-style line at work, nor were they allowed to eat from the grab-and-go venue, with the exception of the yogurt, milk, and cereal that was served at that venue. Participants were also not allowed to eat from the frozen yogurt stand or from the specialty coffee stand. Restricting participants from these foods had the benefit of allowing me to more accurately estimate their nutritional intake (as I had nutrition labels for all restaurant-style foods that were served at work) and to provide the experience of seeing food yet being unable to eat it. This experience, of seeing food and being unable to eat it, will not occur in outer space. Therefore, providing this experience in both the experimental and control conditions provided feelings of deprivation in both conditions, thereby effectively eliminating this deprivation from being a cause of different responses to the two conditions. An excerpt of the control condition instructions is shown below (see Appendix B for complete instructions):

*This Monday, Tuesday, Wednesday, and Thursday, you are to eat breakfast, lunch, and dinner at work. You can eat whatever you want for these meals from the Mezz, the Grill, the Dragon Wagon, and the Sandwich Line. You may also eat the yogurt parfaits and the milk/cereal from the Grab-and-Go area, but not the other foods (not the sandwiches/wraps, variety boxes, or juice). Do NOT order or eat anything from the frozen yogurt stand, the coffee bar (except for plain coffee/tea with no sugar/creamer added), the smoothie line, or the salad bar.*

*For the next four days, after you eat or drink ANYTHING, write that what that food or drink is on the Food Rating Log for that day (the Food Rating Logs are behind this sheet). Please take a look at the Food Rating Log now, and then come back to this instruction sheet.*

*On the Food Rating Log, write down ALL the food and drink ITEMS that you consume, such as "Turkey sandwich," "Green salad with dressing," "French fries," etc. Be sure to include your sides! If you selected cereal/milk from the Grab-and-Go area, be sure to write down what type of cereal and what type of milk, and whether you had all the milk, or just some of it.*

*On the Food Rating Log, for Amount, you can write down "1" if you eat the whole plate of food, "1/2" if you only ate half of it, or "1 bite" if you took one bite and didn't finish the rest. Rate each item that you eat (even if you only ate part of it) using the 1 ("dislike extremely") to 9 ("like extremely") scale that is shown on the Food Rating Log.*

*You can eat snacks at home, but be sure to write them on your Food Rating Log, as well as the quantity that you ate. Please be as specific as possible with these items (e.g., Nature Valley Cinnamon Granola Bar, one package) so that I can estimate what you ate.*

*You can drink water, tea, and black coffee (no soda, and no cream or sugar in any drinks), but be sure to write down every time you drink and how much you drank (e.g., 12oz coffee, 20oz water) on the Food Rating Log, as you would write down food. You do NOT need to rate your drinks using the 1 to 9 scale.*

*Tuesday, Wednesday, Thursday, and Friday morning, meet me between 8:00am and 10:00am to turn your previous day's Food Rating Log.*

## Measures

All measures used in the study are shown below in Table 4.

Table 4 – Measures in the Study

| Aim | Construct | Measure |
|---|---|---|
| **Descriptive Measures** | Food Survey<br>Personality | Work-Specific Food Survey<br>Ten-Item Personality Inventory |
| **Nutrient Intake** | Daily Caloric Intake | Calculated using Food Processor |

| | | |
|---|---|---|
| **Food Satisfaction** | Food Ratings<br>Satisfaction with Variety<br>Food Cravings | Food Rating Log<br>Food Monotony Scale<br>Appetite Scale |
| **Psychological Health** | Mood<br>Social Disconnection<br>Perceived Stress | Brunel Mood Scale<br>Feelings of Social Disconnection Scale<br>Perceived Stress Scale |
| **Physical Health** | Weight Change<br>Self-Reported Health<br>Sleep Difficulties | Weight<br>Self-Reported Health<br>Pittsburgh Sleep Quality Index |
| **Qualitative Measures** | Qualitative Evaluation | Qualitative Questions |

## Descriptive Measures

Prior to starting the study, participants completed a Work-Specific Food Survey (see Appendix A). This measure was used to screen participants and to provide descriptive information on the sample. This measure was not used as a moderator in any analyses. On Friday, participants also completed the Ten-Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann, 2003; see Appendix D). This measure was also used to provide descriptive information on the sample and was not used as a moderator in any analyses.

## Nutrient Intake

**Daily caloric intake.** Daily caloric intake was calculated by entering into The Food Processor the type and amount of food recorded on participants' Food Rating Logs (Appendix C). Caloric intake was summed for each day so that each participant had 8 *daily caloric intake* scores. I also conducted post-hoc analyses to calculate participants' percent of calories from protein, carbohydrates, and fat, as well as to estimate the weight of their total intake.

## Food Satisfaction

**Food ratings.** The Food Rating Log (Appendix C) included a 9-Point Hedonic Scale for each food item consumed, on which participants rated each food from 1 = "dislike extremely" to 9 = "like extremely." This Hedonic Scale was originally developed by the U.S. Armed Forces to measure soldiers' food preferences (Jones et al., 1955; Peryam & Girardot, 1952), but is now used by NASA to assess astronauts' food preferences, as well. For each participant, I averaged their daily food ratings so that each participant had 8 *average daily food rating* scores, with 1 being the lowest possible rating and 9 being the highest possible rating. I also conducted exploratory analyses in which I evaluated each food item's average rating. These exploratory analyses provided insight into which individual food items should be replaced, but these analyses were not included in the study's main analyses.

**Satisfaction with variety.** Every evening (eight evenings total), participants completed the Food Monotony Scale (Appendix E), adapted from questions previously used by Redden (2013) in NASA-funded studies. The scale included three questions, with two questions asking participants to rate their satisfaction with food variety from 1 (indicating lowest satisfaction) to 9 (indicating highest satisfaction). The remaining question asked participants to rate their boredom with food from 1 (extremely bored) to 9 (not at all bored). However, this question was sometimes negatively correlated with the other two questions, suggesting that participants misread the wording of the response options and interpreted 9 as indicating high boredom. Consequently, only the first two items were used in analyses. This resulted in consistent positive correlation between the two items every day. These two items were averaged to calculate 8 *average daily satisfaction with variety* scores, with 1 indicating lowest satisfaction with variety and 9 indicating highest satisfaction with variety.

**Food cravings.** Every evening (eight evenings total), participants completed the Appetite Scale (Appendix F), which included items previously used by Spiegel and colleagues (2004) in NASA-funded research. This scale assesses cravings for sweets, salty food, starchy food, fruits, vegetables, meats, and dairy. Participants rated their desire for each of the food groups from 1 = "not at all" to 9 = "very much." Responses were not averaged; each participant had 8 *daily craving for sweets* scores, 8 *daily craving for meat* scores, etc., with 1 indicating lowest possible craving for that food group and 9 indicating highest possible craving for that food group.

## Psychological Health

**Mood.** Every evening (eight evenings total), participants completed the Brunel Mood Scale (BRUMS; Terry et al., 1999, 2003; Appendix G). The BRUMS is derived from the Profile of Mood States (POMS; McNair, Lorr, & Droppelman, 1971) but is geared toward non-clinical populations, such as athletes. The BRUMS has 24 items and six factors (Terry et al., 1999, 2003). Each of the six factors (anger, confusion, depression, fatigue, tension, vigor) has four adjectives associated with them. Participants rated the extent to which they felt each emotion using a 5-point Likert scale from 0 = "not at all" to 4 = "extremely." For each participant, I created a total daily tension, anger, vigor, confusion, fatigue, and depression score, so that each participant had 8 *daily tension* scores, 8 *daily anger* scores, etc., with 0 indicating the lowest possible amount of that mood and 16 indicating the highest possible amount of that mood.

**Feelings of social disconnection.** Every evening (8 evenings total), participants completed the Feelings of Social Disconnection measure ($\alpha = 0.84$; Eisenberger et al., 2010; Appendix H). This measure contains five items that are rated on a 5-point Likert scale from 1 = "not at all" to 5 = "very much so." The five questions are: (1) "I felt like being around other people," (2) "I felt like being alone," (3) "I felt overly sensitive around others (e.g., my feelings were easily hurt)," (4) "I felt connected to others," and (5) "I felt disconnected from others." Items 1 and 4 are reverse scored. Each participant's responses were averaged (after items 1 and 4 were reverse scored) to provide each participant with 8 *daily feeling of social disconnection* scores, with 1 being the lowest possible feeling of social disconnection and 5 being the highest possible feeling of social disconnection.

**Perceived stress.** Each evening (8 evenings total), participants reported their perceived stress using the 4-item version of the Perceived Stress Scale (PSS-4; Cohen, et al., 1983; Appendix I). The PSS-4 has been shown to have adequate internal consistency ($\alpha$ = .84-.86) and test-retest reliability ($r$ = .85; Cohen, et al., 1983). Greater perceived stress indicates worse psychological health. Traditionally, the scale asks participants to rate how they have felt over the past month, but for the purpose of this study participants were asked to rate how they felt over the past 24 hours. Participants rated their stress on a 5-point Likert scale from 0 = "never" to 4 = "very often." Each participant's responses were summed (after items 2 and 3 were reverse scored) to provide each participant with 8 *daily perceived stress* scores, with 0 being the lowest possible perceived stress and 16 being the highest possible perceived stress.

**Physical Health**

**Weight.** Participants were weighed Monday and Friday mornings of both weeks, prior to eating. Because the participants in this study were used as an astronaut analog sample, and because weight loss in astronauts can lead to health problems (Matsumoto et al., 2011), greater weight loss was used as an indicator of worse health. Participants were able to see their own weight but they were not allowed to see the weight of others. Each participant had two *weight* values for each week.

**Self-reported health.** Every evening (eight evenings total), participants responded to the question, “In general, how would you rate your health today?” (See Appendix J). This wording was used by the World Health Organization (2007) in global surveys. Participants rated their health as excellent, very good, good, fair, or poor, in line with the response options that are common in national studies (Gold, Franks, and Erickson, 1996; Jamoom et al., 2008), instead of the options of “very good” to “very bad” that were used by the WHO. These response options were used to conform to the traditional response options that are used in health psychology and to encourage more variation in responses among the healthy subjects in this study. At the end of the study, each participant had 8 *daily self-reported health* scores, with 1 indicating excellent health and 5 indicating poor health.

**Sleep difficulties.** On Friday morning of each week, participants completed the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989; Appendix K). The PSQI shows high test-retest reliability, high internal consistency ($\alpha = 0.80$ for global score), and good construct validity (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Carpenter & Andrykowski, 1998). The PSQI includes 19 self-rated items that assess seven components: subjective sleep quantity (1 question), sleep latency (2 questions), sleep duration (1 question), habitual sleep efficiency (3 questions), sleep disturbances (9 questions), use of sleep medication (1 question), and daytime dysfunction (2 questions). These seven components are used to compute a global PSQI score. The PSQI traditionally asks about sleep “during the past month,” but for the purposes of this study it was adapted to ask about sleep “during the past four days.”

For one item (item 5), the response choices “less than once a week,” “once or twice a week,” and “three or more times a week” were also adapted to be “less than once,” “once or twice,” and “three or more times.” I computed each participant’s *global sleep score* for each week, with 0 indicating the least possible sleep difficulties and 21 indicating the most possible sleep difficulties.

### Qualitative Measures

After the two-week experiment, I met with participants in a private area to obtain qualitative data on their favorite and least favorite items from the experimental diet, and to inquire about what foods they wanted to see added or removed from the diet. The qualitative questions that were asked are shown in Appendix L.

## Analyses

### Power Analyses

Because I hypothesized a number of null differences, having adequate power was an important issue. Power analyses were therefore conducted prior to starting the study to ensure the sample size was sufficient. G*Power version 3.1.9.2 was used to determine power for the repeated measures analyses. It was determined that the study would have 87% power to detect a significant effect, given the following parameters:

A. A small to medium effect size of Cohen’s d = 0.36.

B. A $p$ value of .10, the significance value that was pre-determined to be used throughout this study.

C. A test-retest reliability of $r = .87$, which was the test-retest reliability of the PSQI global score in a study of primary insomnia (Backhaus et al., 2002) and which was considered a good estimate of test-retest reliability in this study, given that most measures were completed daily.

D. A sample size of N = 12, which was the targeted overall sample size between both conditions because of the parallel crossover nature of the study.

To determine power for the planned one-way analysis, Schoenfeld's crossover study power calculator was used (http://hedwig.mgh.harvard.edu/sample_size/js/js_crossover_quant.html). It was determined that for a *p* value of .10, a within-participant standard deviation of 0.5, and a sample size of 6 participants per condition, I would have 80% power to detect a difference between the two conditions if the true difference between the experimental and control groups was 0.840 units. Based on these power calculations, the target sample size of 6 participants per condition was deemed appropriate, given that the study was more focused on noticeable differences between the two conditions, rather than on minuscule differences that would not be meaningful in the real world.

**Main Analyses**

Data were analyzed using SPSS (SPSS Inc., Chicago, IL, USA). Variants of repeated measures analysis of variance (ANOVA) were used because all dependent variables were continuous and each participant was exposed to both conditions. Pairwise comparisons with Sidak correction were used to follow up on significant omnibus test results. A significance value of $p \leq .10$ was used for all ANOVA and pairwise comparison tests. Reliabilities were computed for each measure.

One measure, global sleep score, was computed just once per condition and therefore had one within-subjects factor (condition). This measure was analyzed via one-way repeated measures ANOVA. One other measure, weight, was computed twice per condition (on Monday and Friday mornings) and therefore had four data points and two within-subjects factors (condition and time). This measure was analyzed using two-way repeated measures ANOVA. The remaining measures (excluding descriptive and exploratory measures) were completed by participants daily and therefore had eight data points and two within-subjects factors (condition and time). These daily measures were also analyzed using two-way repeated measures ANOVA.

Prior to conducting analyses, I had planned to use multivariate ANOVA to analyze the sleep subscales. However, when it was time to analyze the data, it was apparent that the sleep subscales had extremely limited range (0-3), making meaningful analysis of subscales not feasible. The sleep data in this study had an especially limited range because participants generally slept well. Consequently, I decided to only conduct one repeated measures ANOVA on the global sleep score, and to not analyze the subscales. Prior to conducting analyses, I had also planned to use multivariate ANOVA to analyze the mood subscales. However, the mood subscales were not consistently correlated with one another. I decided that running separate repeated measures ANOVAs for the mood subscales would be more appropriate. To summarize, two-way repeated measures ANOVAs were conducted on all dependent variables with the exception of global sleep score, which was assessed via a one-way repeated measures ANOVA.

Laerd Statistics' guides (Lund Research Ltd, 2013a; 2013b) for conducting one-way and two-way repeated measures ANOVAs were used as guides when analyzing data. The first two repeated measures ANOVA assumptions – continuous dependent variables and matched pairs –

were automatically met for all data analyzed in this study. Assumption #3, that there be no significant outliers, was assessed before interpreting results by computing studentized residuals and confirming there were no values +/- 3 standard deviations (for two-way repeated measures ANOVA) or by looking at a box plot of scores and confirming there were no values three times the interquartile range (for one-way repeated measures ANOVA). Assumption #4, that the data be approximately normally distributed, was also assessed prior to interpreting results by conducting a Shapiro-Wilk test on the studentized residuals (for two-way repeated measures ANOVA) or on the scores themselves (for one-way repeated measures ANOVA, for which the distribution of scores within each level of the within-subjects factor is equivalent to the distribution of residuals). Data that were not normally distributed were transformed prior to analysis when doing so led to meaningful improvements in normality. Both square root and log transformation were attempted; log transformation tended to normalize the data better than square root transformation, and consequently only log root transformation was used. If one subscale of a measure was transformed, all the subscales of that measure were transformed the same way. Assumption #5, that the data have sphericity, was assessed via Mauchly's test of sphericity whenever conducting a two-way repeated measures ANOVA. Data for the one-way repeated measures ANOVA automatically met this assumption.

**Exploratory Analyses**

Exploratory analyses were conducted using participants' ratings of individual food items on the Food Rating Log, participants' reported food cravings, and participants' qualitative responses in the post-study qualitative evaluation. Because NASA only flies food that scores 6.0 or higher on the Hedonic Scale, I used participants' hedonic ratings of individual food items to identify foods that scored lower than 6.0 during the experimental condition. I then used participants' reported food cravings and participants' qualitative responses to identify new food items that could fulfill participants' food cravings and score higher on the Hedonic Scale, thereby potentially improving the acceptability of the experimental diet as a whole. These exploratory analyses are elaborated upon further in the discussion.

**Post Hoc Analyses**

To calculate percent of calories from macronutrients, I used The Food Processor to obtain each participant's average percent of calories from protein, carbohydrates, and fat in the control and experimental conditions. I then computed the average macronutrient percentages for each condition. Next, I used those average percentages, along with the previously obtained average caloric intake, to calculate the average intake of protein, carbohydrates, and fat, in grams, in each condition. The following calculator was used to convert percentages into grams: http://macronutrientcalculator.com.

I also used The Food Processor to obtain each participant's average intake, in grams, from food and fluids in each condition. I then averaged across participants to obtain food and fluid intake estimates for each condition. This method was used, instead of merely adding up participants' reported fluid intake, because a large portion of one's water intake comes from food and I anticipated participants would consume more water from their food in the control condition than in the experimental condition. In the control condition, participants were allowed to eat water-rich foods such as milk, fresh fruit, and cooked oatmeal, whereas in the experimental condition, these water-rich and therefore high mass and high volume foods were excluded. Consequently, this method of summing the weight of food and fluid intake provided a more accurate estimate of participants' water intake than would have been obtained from summing participants' reported fluid intake alone.

However, my estimates of participants' water intake were nevertheless rough approximations, for several reasons. First, food is comprised of not only protein, carbohydrates, fat, and water, but also alcohol, ash, and fiber. Second, fiber is sometimes subtracted from nutrition labels' carbohydrate sections, and sometimes not, making it difficult to calculate actual carbohydrate intake. Third, and most influentially, the accuracy of participants' reported fluid intake was questionable. The study instructions did not emphasize the importance of recording fluid intake as much as they emphasized the importance of recording all food. Consequently, participants reported their fluid intake with much less accuracy and reliability. Many participants turned in food logs with no reported fluid intake. When I noticed they did this, I would ask them to estimate the quantity of fluids that they had drank the previous day. However, these retrospective reports were likely inaccurate. Additionally, one participant turned in foods logs late, and these late food logs did not report fluid intake. Asking this participant to retrospectively report previous days' fluid intake could have resulted in highly inaccurate data. Consequently, this participant was excluded from all *post hoc* analyses.

**Computing Caloric Intake**

Participants' self-reports were used to calculate intake in both conditions. Self-report was used, as opposed to measuring leftovers, because it could have disrupted or disturbed non-participating employees if participants had saved their leftovers during the control condition. For instance, asking a participant to pour a half-eaten plate of steak, fries, and salad (one of the meals eaten by a participant during the control condition) into a plastic bag and then carry that bag around all day could have disturbed other employees. Even asking participants to drop off their uneaten food somewhere within the workplace would have been too disruptive, as plates of partially-eaten food stored at room temperature quickly become offensive. Consequently, participants were not asked to store their leftovers during the control condition. The experimental food, on the other hand, was low-volume and easily stored in a plastic bag, allowing me to ask participants to turn in their leftover experimental food. Nevertheless, so as to use consistent measurement in both conditions, self-report was used to calculate caloric intake.

Measurement of leftovers was only conducted to verify and clarify food logs in the experimental condition. For instance, if I noticed that the leftovers did not match up with the food logs (which rarely occurred), I spoke with participants to verify their food logs were correct. Some participants, especially those who ate fewer calories per day and those who wanted to try all the different foods, reported taking "one bite" or "one sip" of food. When I noticed that this was occurring, I did background research – prior to doing any statistical analyses – to determine the weight, in grams, of an average sip or bite. Researchers have found that an adult's mean bite size is $10.3 \pm 4.0$ grams, with a "small bite" frequently defined as 5 grams and a "large bite" frequently defined as 15 grams (Zijlstra, Wijk, Mars, Stafleu, & Graaf, 2009). In natural drinking conditions, an average sip is about 16 mL (Bennett, Pascal, Van Lieshout, Pelletier, & Steele, 2008). Consequently, for all participants in this study, I calculated "one bite" as 10 grams, "two bites" as 20 grams, etc. If a participant specified it was a "small bite," I recorded that as 5 grams. So as not to overestimate food intake the experimental condition, and so as to be as consistent as possible, I also coded "one sip" as 10 grams. In a few instances, participants reported eating "one handful" of jerky mix. Given that the size of a "handful" can vary from person to person, I weighed the leftovers and found the "handful" reported by participants was approximately 30 grams. “One handful” was therefore recorded as 30 grams. In one instance, a participant reported an ambiguous “few” bites of food. In this instance, I weighed the leftovers and found the participant ate 90 grams, and I therefore recorded the participant’s intake as such.

When participants forgot to rate an item, which happened just a few times, I asked them via email or text how they would rate that item. When participants in the control condition described their food in overly-generalized terms (e.g., “4oz yogurt,” “2 slices bread”), I asked them to specify further (e.g., “4oz full-fat yogurt,” “white bread”). One participant ate an unexpectedly few number of calories and meals per day. I asked this participant about the low food intake, and the participant confirmed the food logs were correct.

**Computing Participants’ Daily Food Ratings**

If a participant ate half of a food item on Monday and finished that food item on Wednesday, only their Monday rating was included when calculating that participant’s daily average food rating. On two instances, one participant ate half of a food item in the morning and the other half of that food item in the afternoon. In these instances, I averaged the food ratings and counted them as a single rating. If a participant smelled or tasted but did not eat a food item, the ratings were included in analyses, just as if the food had been eaten.

Three participants requested and ate additional food items during days 3 and 4 of the experimental condition. Providing these additional food items was considered acceptable because the trading and sharing of food would likely be common during spaceflight. One participant was provided with another Asian Noodle and Indian Potato Entrée, one participant was provided with two more BBQ Chicken Sandwiches, and one participant was provided with two more applesauce pouches and two more yogurt pouches. Participants' ratings of these additional food items were included when calculating participants' daily food ratings.

### Computing Average Ratings of Particular Food Items

When computing the average rating a particular food item, I averaged ratings if one participant rated the food twice in one day. However, I used only the first rating if a participant rated the same food item on two separate days. This is the same way that I assessed ratings when computing participants' daily food ratings. However, when computing average ratings of particular food items, I did not include the ratings of any additional items that were requested by participants, so that each participant's evaluations were weighted the same (e.g., a participant who requested another Chicken Sandwich did not get a greater say over the Chicken Sandwich's average food rating than a participant who did not request another Chicken Sandwich). Two items (Italian-Style Sandwich and Turkey Jerky) were provided twice in the experimental condition. All ratings for the Italian-Style Sandwiches were averaged together to compute its average food rating. The same approach was used for Turkey Jerky.

## Results

### Descriptive Results

Eight individuals participated in the study. One participant had a medical emergency on Thursday of the Control week, leading to extreme changes in diet (e.g., not eating all day), the inability to weigh the participant in-person, and the delayed completion of surveys. Additionally, it was unknown if the medical event led to altered eating on the other days of the study. Consequently, this participant was excluded from all analyses, leaving a sample size of N = 7.

The remaining seven participants were comprised of four females (*M* weight = 166.8 pounds) and three males (*M* weight = 180.63 pounds). Participants were not asked to report their precise age, but they all appeared to be in their late 20's to early 30's – largely mirroring NASA-selected astronaut candidates, whose average age is 34 (NASA Astronaut Selection Program, n.d.). The seven participants were of Caucasian descent. A sample that more accuracy reflected the U.S. population would have been preferred, but the sample nevertheless reflected NASA's former astronaut population (see list of NASA's former astronauts here: https://www.nasa.gov/astronauts/biographies/astronauts/former). Prior to participating in the study, participants reported they ate the breakfast that was served at work a mean of 2.43 times a week (*SD* = 0.79), the lunch a mean of 3.86 times a week (*SD* = 0.38), and the dinner a mean of 3.00 times a week (*SD* = 0.58). Prior to participating in the study, participants reported most commonly eating their meals at the cafeteria/Mezz at work (N = 6), at their desks (N = 5), and at home (N = 4). No participant reported that they ate foods such as juice or meal replacement bars most days. However, participants did report having food patterns, such as eating protein shakes or oatmeal most days.

The anonymous personality survey that participants completed on the last Friday of the study revealed that participants did not have extremely unusual personalities, as compared to norms based on 1,813 respondents (Gosling, Rentfrow, & Potter, 2014). Compared to these norms, participants in this study scored 1.42 points higher on Extroversion, 0.60 points higher on Emotional Stability, and within a half point of every other measured personality trait. These comparisons were computed using the worksheet designed by DeNeui (n.d.) to compare TIPI scores to TIPI norms (Gosling et al., 2014). These comparisons are shown in Table 5, with each participant depicted as a number.

Descriptive results for all measures in this study are shown in Tables 6 through 11.

Table 5 – Personality Results

| | | Personality Traits | | | | |
|---|---|---|---|---|---|---|
| | | **Extraversion** | **Agreeableness** | **Conscientiousness** | **Emotional Stability** | **Openness** |
| **Means** | **Norms*** | 4.44 | 5.23 | 5.40 | 4.83 | 5.38 |
| | **Study Mean**** | 5.86 | 5.14 | 5.07 | 5.43 | 5.64 |
| **Anonymous Participants** | **1** | Medium High 5.5 | Medium High 5.5 | Medium Low 4.5 | Medium High 6 | High 6.5 |
| | **2** | High 6.5 | High 7 | Medium Low 5 | High 6.5 | High 6.5 |
| | **3** | Medium High 5.5 | Low 2.5 | Low 4 | Low 3 | Low 4 |
| | **4** | High 6.5 | Medium Low 4.5 | Medium Low 5 | Medium High 5 | Medium High 6 |
| | **5** | High 6.5 | Medium Low 4.5 | Medium Low 4.5 | Medium High 5.5 | Medium Low 4.5 |
| | **6** | Medium High 4.5 | Medium High 6 | Medium High 6 | Medium High 5.5 | Medium High 5.5 |
| | **7** | High 6 | Medium High 6 | Medium High 6.5 | High 6.5 | High 6.5 |

*Norms based on 1813 respondents (Gosling et al., 2014)

**Study mean is the mean of the seven participants' responses

Table 6 – Descriptive Analyses of Caloric Intake Outcome

| Caloric Intake | | | | | | | |
|---|---|---|---|---|---|---|---|
| Condition | Condition *M* | Condition *SE* | Condition 95% CI | Temporal α | Day | Daily *M* | Daily *SD* |
| Control | 1785.11 | 230.15 | [1221.96, 2348.25] | .863 | 1 | 1720.79 | 693.59 |
| | | | | | 2 | 1895.09 | 696.17 |
| | | | | | 3 | 1837.36 | 895.42 |
| | | | | | 4 | 1687.19 | 571.37 |
| Space Food | 1810.71 | 164.41 | [1408.35, 2213.06] | .752 | 1 | 1975.62 | 585.06 |
| | | | | | 2 | 1799.32 | 388.75 |
| | | | | | 3 | 1788.50 | 552.97 |
| | | | | | 4 | 1679.37 | 722.57 |

Table 7 – Descriptive Analyses of Food Satisfaction Outcomes

| Condition | Condition *M* | Condition *SE* | Condition 95% CI | Temporal α | Day | Daily *M* | Daily *SD* |
|---|---|---|---|---|---|---|---|
| Daily Food Rating (1 = Dislike Extremely, 9 = Like Extremely) | | | | | | | |
| Control | 7.13 | 0.26 | [6.49, 7.76] | .215 | 1 | 7.46 | 0.76 |
| | | | | | 2 | 7.20 | 0.47 |
| | | | | | 3 | 7.05 | 1.23 |
| | | | | | 4 | 6.80 | 1.99 |
| Space Food | 5.78 | 0.26 | [5.16, 6.41] | .831 | 1 | 5.54 | 0.79 |
| | | | | | 2 | 5.75 | 1.03 |
| | | | | | 3 | 5.62 | 0.78 |
| | | | | | 4 | 6.22 | 0.68 |
| Satisfaction with Variety (1 = Lowest Satisfaction, 9 = Highest Satisfaction) | | | | | | | |
| Control | 6.00 | 0.49 | [4.81, 7.19] | .736 | 1 | 6.57 | 0.98 |
| | | | | | 2 | 6.14 | 1.18 |
| | | | | | 3 | 5.93 | 2.07 |
| | | | | | 4 | 5.36 | 2.30 |
| Space Food | 4.25 | 0.41 | [3.25, 5.25] | .764 | 1 | 4.57 | 1.27 |
| | | | | | 2 | 4.43 | 2.07 |
| | | | | | 3 | 3.93 | 1.27 |
| | | | | | 4 | 4.07 | 0.67 |
| Daily Sweet Cravings (1 = Not at all, 9 = Very Much) | | | | | | | |
| Control | 3.21 | 0.84 | [1.16, 5.27] | .906 | 1 | 3.71 | 2.69 |
| | | | | | 2 | 3.29 | 2.43 |
| | | | | | 3 | 2.71 | 2.36 |
| | | | | | 4 | 3.14 | 2.41 |
| Space Food | 2.39 | 0.83 | [0.36, 4.43] | .958 | 1 | 1.71 | 1.50 |
| | | | | | 2 | 2.86 | 3.29 |
| | | | | | 3 | 2.71 | 2.56 |
| | | | | | 4 | 2.29 | 1.70 |
| Daily Starch Cravings (1 = Not at all, 9 = Very Much) | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Control | 3.29 | 0.59 | [1.84, 4.73] | .717 | 1 | 3.29 | 1.89 |
| | | | | | 2 | 2.86 | 1.57 |
| | | | | | 3 | 3.14 | 2.48 |
| | | | | | 4 | 3.86 | 2.85 |
| Space Food | 4.18 | 0.91 | [1.95, 6.41] | .931 | 1 | 3.71 | 2.06 |
| | | | | | 2 | 4.14 | 3.67 |
| | | | | | 3 | 4.71 | 2.81 |
| | | | | | 4 | 4.14 | 2.41 |
| Daily Fruit Cravings (1 = Not at all, 9 = Very Much) | | | | | | | |
| Control | 2.36 | 0.34 | [1.53, 3.19] | .432 | 1 | 2.86 | 1.46 |
| | | | | | 2 | 2.14 | 1.21 |
| | | | | | 3 | 1.71 | 1.11 |
| | | | | | 4 | 2.71 | 1.98 |
| Space Food | 3.14 | 0.54 | [1.83, 4.46] | .716 | 1 | 2.57 | 1.72 |
| | | | | | 2 | 2.71 | 1.89 |
| | | | | | 3 | 3.86 | 2.19 |
| | | | | | 4 | 3.43 | 1.90 |
| Daily Vegetable Cravings (1 = Not at all, 9 = Very Much) | | | | | | | |
| Control | 4.57 | 0.74 | [2.77, 6.37] | .797 | 1 | 5.57 | 2.64 |
| | | | | | 2 | 4.43 | 2.99 |
| | | | | | 3 | 4.00 | 2.71 |
| | | | | | 4 | 4.29 | 2.21 |
| Space Food | 6.29 | 0.48 | [5.12, 6.45] | .497 | 1 | 6.14 | 2.19 |
| | | | | | 2 | 8.00 | 1.15 |
| | | | | | 3 | 5.43 | 2.57 |
| | | | | | 4 | 5.57 | 2.51 |
| Daily Meat Cravings (1 = Not at all, 9 = Very Much) | | | | | | | |
| Control | 5.18 | 0.93 | [2.90, 7.46] | .907 | 1 | 5.71 | 2.29 |
| | | | | | 2 | 4.43 | 3.21 |
| | | | | | 3 | 4.86 | 3.34 |
| | | | | | 4 | 5.71 | 2.21 |
| Space Food | 6.61 | 1.06 | [4.02, 9.19] | .832 | 1 | 7.00 | 3.21 |
| | | | | | 2 | 7.71 | 1.80 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | 3 | 5.86 | 3.58 |
| | | | | | 4 | 5.86 | 3.49 |
| Daily Dairy Cravings (1 = Not at all, 9 = Very Much) | | | | | | | |
| Control | 3.61 | 0.69 | [1.91, 5.30] | .858 | 1 | 3.86 | 1.95 |
| | | | | | 2 | 3.14 | 2.12 |
| | | | | | 3 | 3.71 | 2.56 |
| | | | | | 4 | 3.71 | 2.06 |
| Space Food | 3.86 | 0.64 | [2.29, 5.42] | .812 | 1 | 3.71 | 1.80 |
| | | | | | 2 | 4.86 | 1.86 |
| | | | | | 3 | 3.43 | 2.23 |
| | | | | | 4 | 3.43 | 2.51 |

Table 8 – Descriptive Analyses of Psychological Health Outcomes

| Condition | Condition *M* | Condition *SE* | Condition 95% CI | Temporal α | Day | Daily *M* | Daily *SD* |
|---|---|---|---|---|---|---|---|
| Daily Anger (0 = Lowest possible anger, 16 = Highest possible anger) | | | | | | | |
| Control | 1.32 | 0.60 | [-0.157, 2.800] | .941 | 1 | 1.00 | 1.00 |
| | | | | | 2 | 1.57 | 2.07 |
| | | | | | 3 | 1.57 | 2.15 |
| | | | | | 4 | 1.14 | 1.46 |
| Space Food | 1.72 | 0.75 | [-0.113, 3.542] | .862 | 1 | 1.43 | 1.51 |
| | | | | | 2 | 2.71 | 3.73 |
| | | | | | 3 | 1.71 | 1.89 |
| | | | | | 4 | 1.00 | 1.53 |
| Daily Confusion (0 = Lowest possible confusion, 16 = Highest possible confusion) | | | | | | | |
| Control | 0.964 | 0.68 | [-0.700, 2.629] | .980 | 1 | 1.14 | 1.77 |
| | | | | | 2 | 1.00 | 1.83 |
| | | | | | 3 | 1.00 | 2.24 |
| | | | | | 4 | 0.71 | 1.50 |
| Space Food | 1.321 | 0.70 | [-0.38, 3.024] | .856 | 1 | 0.86 | 1.21 |
| | | | | | 2 | 1.86 | 3.08 |
| | | | | | 3 | 1.29 | 2.21 |
| | | | | | 4 | 1.29 | 1.90 |
| Daily Depression (0 = Lowest possible depression, 16 = Highest possible depression) | | | | | | | |
| Control | 0.96 | 0.77 | [-0.916, 2.845] | .980 | 1 | 0.71 | 1.50 |
| | | | | | 2 | 1.14 | 2.27 |
| | | | | | 3 | 1.29 | 2.56 |
| | | | | | 4 | 0.71 | 1.89 |
| Space Food | 1.39 | 0.83 | [-0.631, 3.417] | .863 | 1 | 1.43 | 1.27 |
| | | | | | 2 | 2.00 | 4.04 |
| | | | | | 3 | 1.29 | 2.36 |
| | | | | | 4 | 0.86 | 1.87 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Daily Fatigue (0 = Lowest possible fatigue, 16 = Highest possible fatigue) | | | | | | | |
| Control | 5.32 | 1.14 | [2.525, 8.117] | .943 | 1 | 6.00 | 3.56 |
| | | | | | 2 | 5.29 | 3.20 |
| | | | | | 3 | 5.86 | 3.39 |
| | | | | | 4 | 4.14 | 2.91 |
| Space Food | 5.04 | 1.315 | [1.817, 8.255] | .934 | 1 | 6.43 | 5.47 |
| | | | | | 2 | 5.43 | 4.08 |
| | | | | | 3 | 4.43 | 2.07 |
| | | | | | 4 | 3.86 | 2.67 |
| Daily Tension (0 = Lowest possible tension, 16 = Highest possible tension) | | | | | | | |
| Control | 1.964 | 0.725 | [0.191, 3.737] | .924 | 1 | 1.43 | 1.62 |
| | | | | | 2 | 2.57 | 2.30 |
| | | | | | 3 | 2.00 | 1.83 |
| | | | | | 4 | 1.86 | 2.61 |
| Space Food | 1.357 | 0.553 | [0.003, 2.711] | .731 | 1 | 0.86 | 1.86 |
| | | | | | 2 | 1.29 | 1.70 |
| | | | | | 3 | 2.43 | 2.82 |
| | | | | | 4 | 0.86 | 1.07 |
| Daily Vigor (0 = Lowest possible vigor, 16 = Highest possible vigor) | | | | | | | |
| Control | 6.571 | 1.403 | [3.138, 10.005] | .947 | 1 | 6.29 | 4.27 |
| | | | | | 2 | 7.14 | 3.85 |
| | | | | | 3 | 6.43 | 4.12 |
| | | | | | 4 | 6.43 | 3.74 |
| Space Food | 6.250 | 1.393 | [2.841, 9.659] | .929 | 1 | 6.29 | 4.57 |
| | | | | | 2 | 5.86 | 4.06 |
| | | | | | 3 | 6.00 | 3.83 |
| | | | | | 4 | 6.86 | 3.72 |
| Social Disconnection (1 = Not At all, 5 = Extremely) | | | | | | | |
| Control | 3.61 | 0.69 | [1.91, 5.30] | .895 | 1 | 2.09 | 0.76 |
| | | | | | 2 | 2.20 | 0.56 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | 3 | 2.00 | 0.59 |
| | | | | | 4 | 2.23 | 0.62 |
| Space Food | 3.86 | 0.64 | [2.29, 5.42] | .794 | 1 | 2.17 | 0.92 |
| | | | | | 2 | 2.40 | 1.11 |
| | | | | | 3 | 2.40 | 0.61 |
| | | | | | 4 | 1.89 | 0.48 |
| Perceived Stress (0 = Lowest possible perceived stress, 16 = Highest possible perceived stress) | | | | | | | |
| Control | 5.46 | 0.81 | [3.47, 7.46] | .819 | 1 | 4.00 | 2.45 |
| | | | | | 2 | 5.86 | 1.21 |
| | | | | | 3 | 5.71 | 3.45 |
| | | | | | 4 | 6.29 | 3.04 |
| Space Food | 4.96 | 1.11 | [2.24, 7.69] | 0.929 | 1 | 4.57 | 3.15 |
| | | | | | 2 | 4.86 | 3.89 |
| | | | | | 3 | 5.29 | 3.09 |
| | | | | | 4 | 5.14 | 2.73 |

Table 9 – Descriptive Analyses of Physical Health Outcomes

| Weight (in pounds) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Condition | Condition *M* | Condition *SE* | Condition 95% CI | Temporal α | Day | Daily *M* | Daily *SD* |
| Control | 171.89 | 10.05 | [147.31, 196.47] | .999 | 1 | 171.93 | 26.43 |
| | | | | | 5 | 171.86 | 26.76 |
| Space Food | 171.39 | 10.24 | [146.35, 196.44] | .999 | 1 | 172.47 | 27.28 |
| | | | | | 5 | 170.31 | 26.89 |
| Daily Self-Reported Health (1 = Excellent, 5 = Very Poor) | | | | | | | |
| Control | 2.50 | 0.16 | [2.10, 2.90] | .847 | 1 | 2.56 | 0.53 |
| | | | | | 2 | 2.56 | 0.53 |
| | | | | | 3 | 2.57 | 0.53 |
| | | | | | 4 | 2.29 | 0.49 |
| Space Food | 2.68 | 0.14 | [2.33, 3.02] | .369 | 1 | 2.57 | 0.79 |
| | | | | | 2 | 2.57 | 0.79 |
| | | | | | 3 | 2.71 | 0.49 |
| | | | | | 4 | 2.86 | 0.38 |
| Global Sleep Score (0 = Lowest possible sleep difficulty, 21 = Highest possible sleep difficulty) | | | | | | | |
| Control | 4.43 | 0.90 | [1.24, 6.62] | n/a | 5 | 4.50 | 2.35 |
| Space Food | 3.29 | 1.02 | [0.80, 5.77] | n/a | 5 | 3.50 | 2.81 |

## Nutrient Intake

**Did condition or time impact caloric intake?** No. A two-way repeated measures ANOVA was conducted on two within-subjects factors of condition (control, experimental) and time (day 1, day 2, day 3, day 4) to determine the effect of condition over time on caloric intake. Analysis of studentized residuals showed there were no outliers. Caloric intake met the normality assumption, as confirmed by non-significant Shapiro-Wilk tests of normality ($p > .05$) for all studentized residuals. The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = .454$, $p = .995$. The time term also had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 3.464$, $p = .635$. There was no statistically significant interaction between condition and time on caloric intake, $F(3, 18) = .378$, $p = .770$, partial $\eta^2 = .059$, nor was there a statistically significant main effect of condition on caloric intake, $F(1,6) = .039$, $p = .850$, $\eta^2 = .006$. There was also no statistically significant main effect of time on caloric intake, $F(3,18) = .523$, $p = .672$, partial $\eta^2 = .080$. These results, along with individual data points, are shown in Figure 1. In this figure and all that follow it, each colored line represents an individual participant, whereas the solid black line represents the mean of all participants. The dotted line down the center separates the control and experimental conditions. The letters and numbers on the X-axis represent the condition and day of the study. For instance, "C1" = Control Day 1 (Monday), "E2" = Experimental Day 2 (Tuesday), etc.

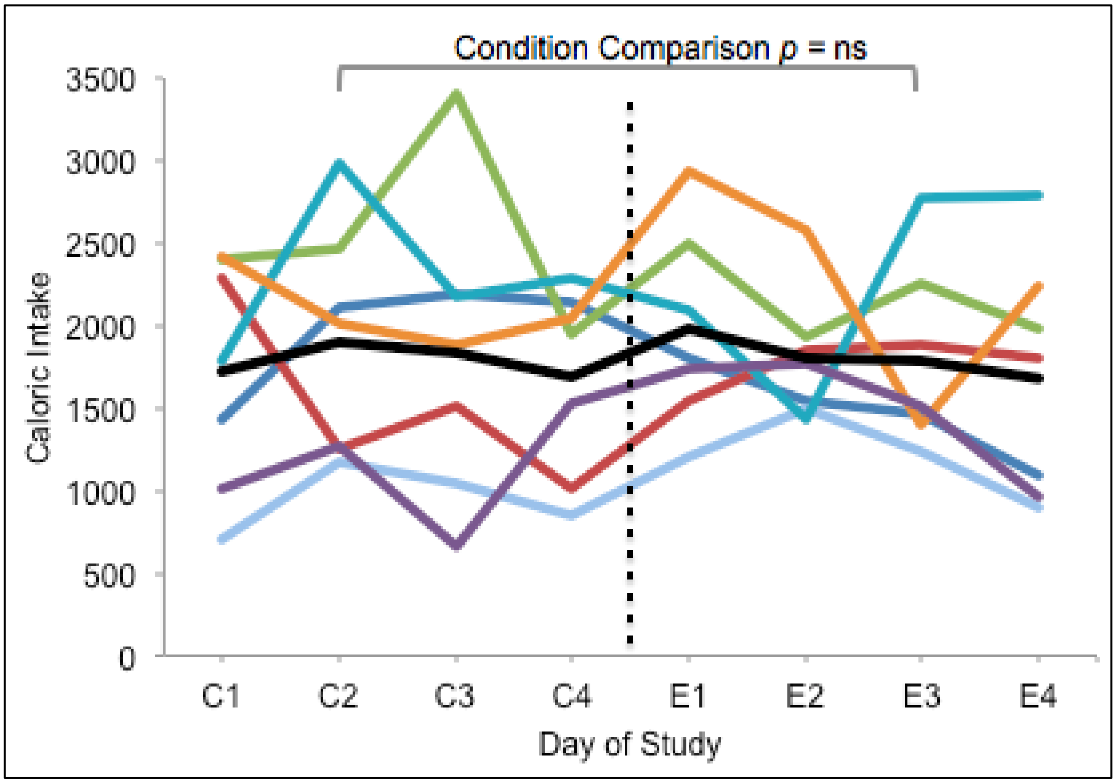


*Figure 1.* Participants' caloric intake

**Satisfaction with Food**

**Did condition or time impact food ratings?** Yes, condition significantly impacted food ratings, although time and their interaction term did not. A two-way repeated measures ANOVA was conducted to determine the effect of condition over time on food ratings. Analysis of studentized residuals showed there were no outliers. Food ratings were normally distributed ($p >$ .05 for all Shapiro-Wilk tests of normality on studentized residuals) with the exception of Day 4 of the control condition ($p$ = .009). Due to all other residuals being normally distributed, this violation was deemed not severe enough to require transformation. Mauchly's test of sphericity revealed that the assumption of sphericity had been violated for the two-way interaction, $\chi^2(5)$ = 15.770, $p$ = .009, and consequently the Greenhouse-Geisser method was used for interpreting the interaction. The time term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term, $\chi^2(5) = 5.607$, $p = .355$. There was no statistically significant interaction between condition and time on food ratings, $F(1.287, 7.723) = 1.483$, $p = .271$, $\varepsilon = .429$. However, there was a statistically significant main effect of condition on food rating, $F(1,6) = 32.233$, $p = .001$, partial $\eta^2 = .843$. Pairwise comparisons using Sidak correction revealed the food in the experimental condition was rated lower than the food in the control condition by 1.345 points on the 9-point Hedonic Scale ($p = .001$). There was no statistically significant main effect of time on food ratings, $F(3,18) = .008$, $p = .965$, partial $\eta^2 = .015$. These results, along with individual data points, are shown in Figure 2.

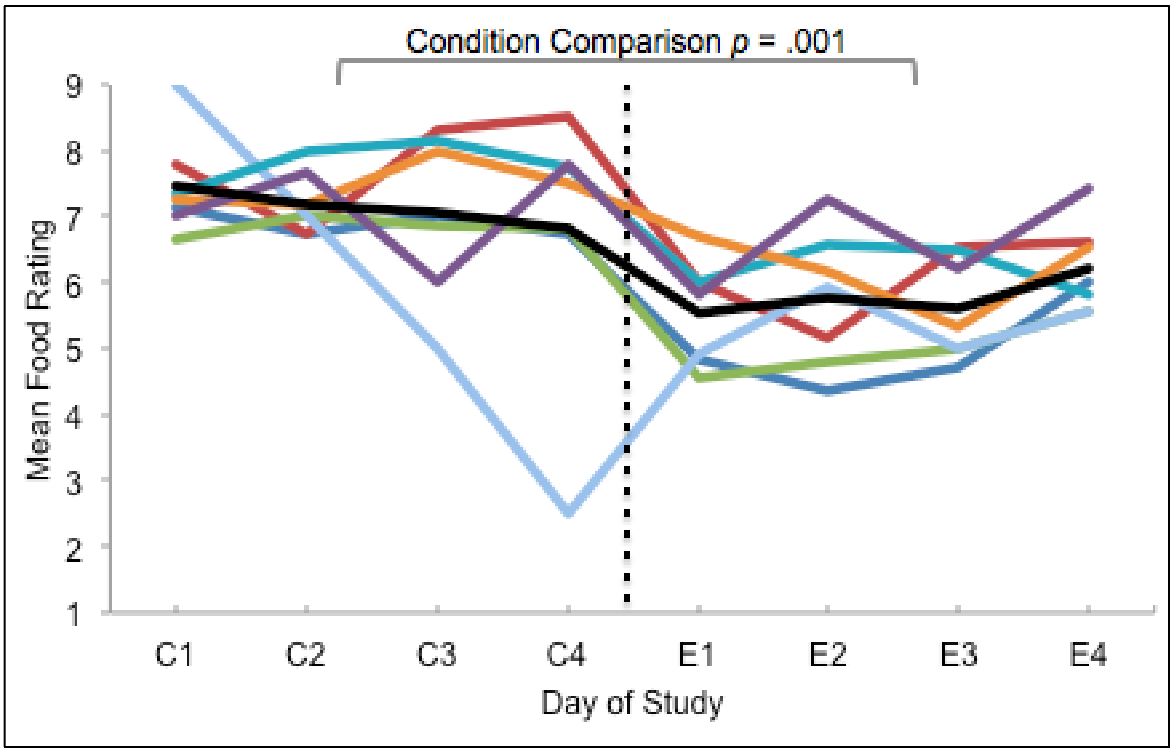


*Figure 2.* Participants' mean daily food ratings

**Did condition or time impact satisfaction with variety?** Yes, condition significantly impacted satisfaction with variety, but time and their interaction term did not. A two-way repeated measures ANOVA was run to determine the effects of condition over time on satisfaction with variety. Analysis of studentized residuals showed there were no outliers. Satisfaction with variety met the normality assumption, as confirmed by non-significant Shapiro-Wilk tests of normality ($p > .05$) for all studentized residuals. The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 5.670$, $p = .349$. The main effect of time also had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 2.359$, $p = .801$. There was no statistically significant interaction between condition and time on satisfaction with variety, $F(3,18) = 0.259$, $p = .854$, partial $\eta^2 = .041$. However, there was a statistically significant main effect of condition on satisfaction with variety, $F(1,6) = 13.025$, $p = .011$, partial $\eta^2 = .685$. Pairwise comparisons using Sidak correction revealed that participants reported lower satisfaction with variety in the experimental condition than they did in the control condition by 1.750 points on the 9-point scale ($p = .011$). There was no statistically significant main effect of time on satisfaction with variety, $F(3,18) = 1.525$, $p = .242$, partial $\eta^2 = .203$. These results, along with individual data points, are shown in Figure 3.

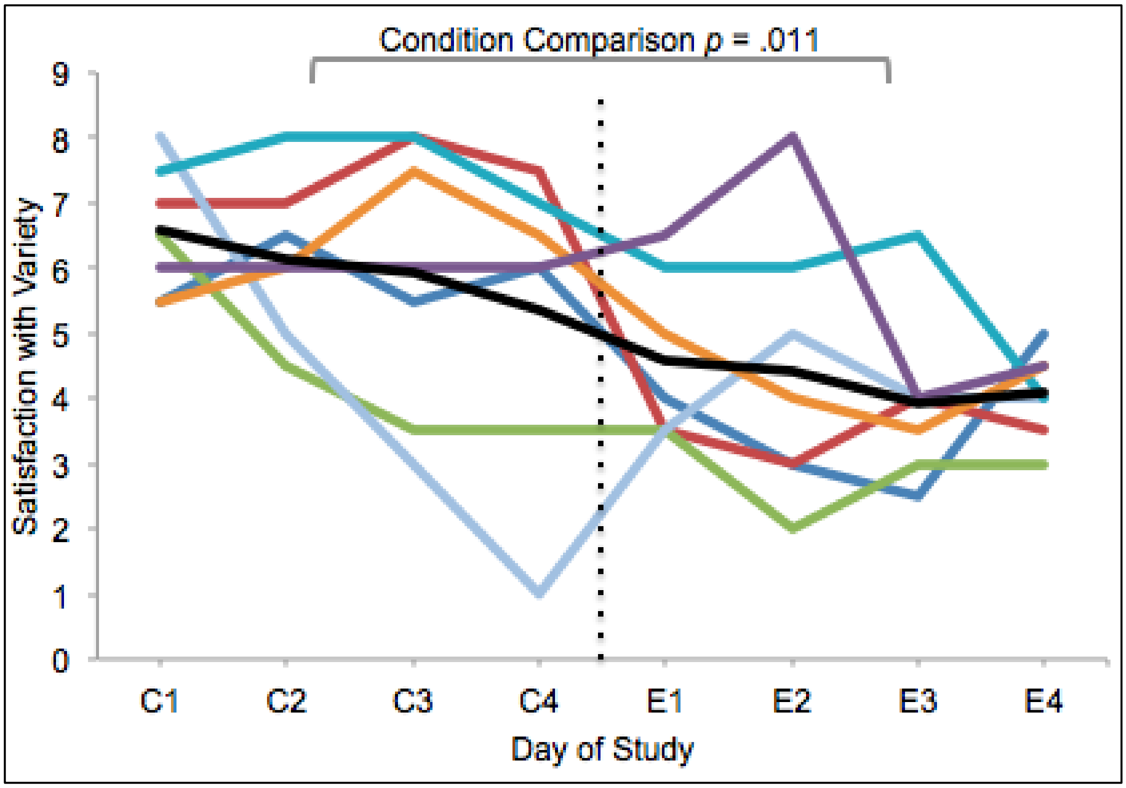


*Figure 3.* Participants' satisfaction with variety

**Did condition or time impact cravings for sweets?** Yes, condition significantly impacted craving for sweets, but time and their interaction did not. A two-way repeated measures ANOVA was run to determine the effects of condition over time on cravings for sweets. Analysis of studentized residuals showed there were no outliers. All studentized residuals met the normality assumption, as indicated by non-significant Shapiro-Wilk tests of normality ($p >$ .05), with the exception of control days 1 and 2. Log transformation and square root transformation were attempted; both approaches increased the number of studentized residuals that were non-normal. However, ANOVA is robust to violations of normality (Schmider, Ziegler, Danay, Beyer, & Bühner, 2010), and I therefore ran the analyses on the original, non-transformed data. The interaction term had sphericity, as confirmed by a non-significant

Mauchly's test of sphericity term $\chi^2(5) = 2.917$, $p = .718$. The time term also had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 3.439$, $p = .639$. There was no statistically significant interaction between condition and time on cravings for sweets, $F(3,18) = 1.629$, $p = .218$, partial $\eta^2 = .214$. However, there was a statistically significant main effect of condition on craving for sweets, $F(1,6) = 5.308$, $p = .061$, partial $\eta^2 = .469$. Pairwise comparisons using Sidak correction revealed that participants in the experimental condition reported craving sweets significantly less (0.82 points lower on the 9-point scale) than participants in the control condition ($p = .061$). There was no main effect of time on craving for sweets, $F(3,18) = .422$, $p = .739$, partial $\eta^2 = .066$. These results, along with individual data points, are shown in Figure 4. One participant reported "1" all days. To make this participant's data more visibly distinct from another participant who reported "1" on all but one day, square markers were added to one participant's data.

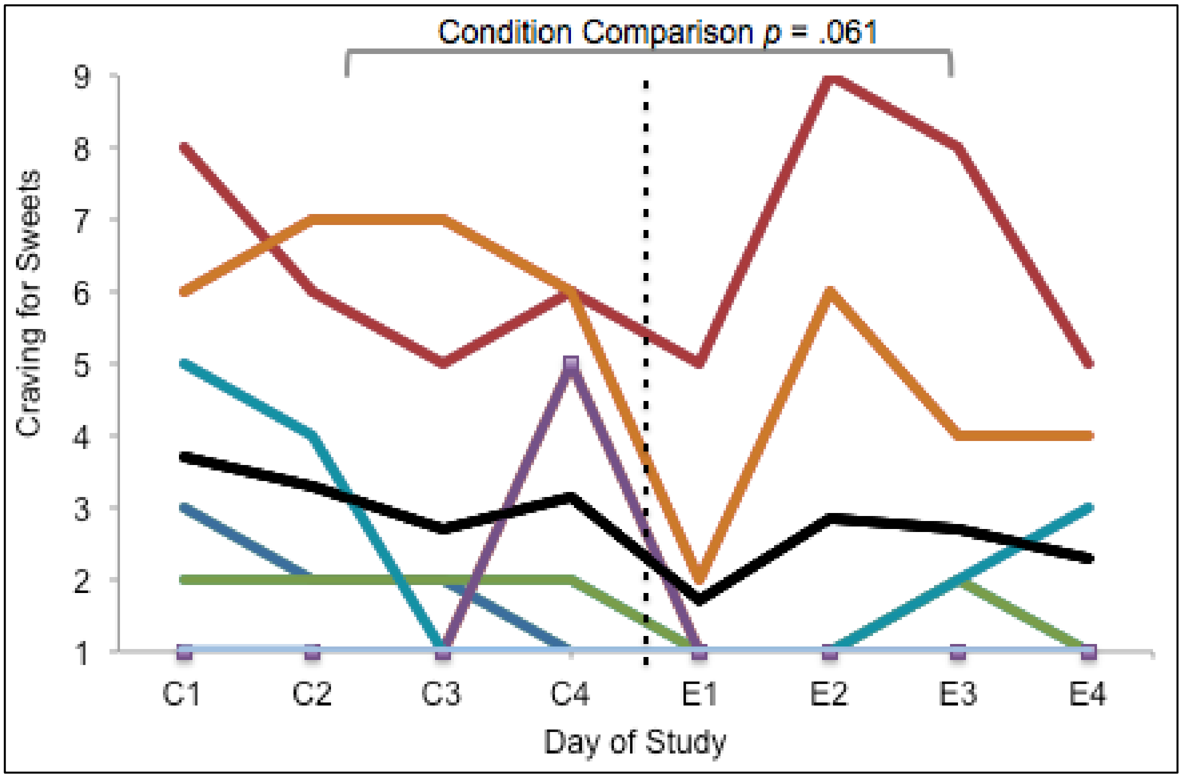


*Figure 4.* Participants' cravings for sweets

**Did condition or time impact cravings for salty food?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on cravings for salty food. Analysis of studentized residuals showed there were no outliers. All studentized residuals met the normality assumption, as confirmed by non-significant Shapiro-Wilk tests of normality ($p > .05$). The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 3.230$, $p = .671$. The time term also had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 5.826$, $p = .332$. There was no statistically significant interaction between condition and time on cravings for salty food, $F(3,18) = 0.785$, $p = .518$, partial $\eta^2 = .116$. There was also no significant main effect of condition on craving for salty food, $F(1,6) = 2.299$, $p = .180$, partial $\eta^2 = .277$, nor of time on craving for salty food, $F(3,18) = 0.453$, $p = .718$, partial $\eta^2 = .070$.

**Did condition or time impact cravings for starches?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on cravings for starches. Analysis of studentized residuals showed there were no outliers. All studentized residuals met the normality assumption, as confirmed by non-significant Shapiro-Wilk tests of normality ($p > .05$), with the exception of the residuals for experimental day 3. ANOVA is robust to violations of normality (Schmider et al., 2010) so the ANOVA was still performed. The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 5.175$, $p = .404$. The time term also had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 7.449$, $p = .198$. There was no statistically significant interaction between condition and time on cravings for starches, $F(3,18) = .476$, $p = .703$, partial $\eta^2 = .073$. There was also no significant main effect of condition on craving for starches, $F(1,6) = .777$, $p = .412$, partial $\eta^2 = .115$, nor of time on craving for starches, $F(3,18) = .308$, $p = .820$, partial $\eta^2 = .049$.

**Did condition or time impact cravings for fruit?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on cravings for fruit. Analysis of studentized residuals showed there were no outliers. A majority of studentized residuals met the normality assumption, as confirmed by non-significant Shapiro-Wilk tests of normality ($p > .05$). However, the residuals for control day 3, control day 4, and experimental day 2 were non-normal. ANOVA is robust to violations of normality (Schmider et al., 2010) so the ANOVA was still performed. The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 2.255$, $p = .816$, as did the time term $\chi^2(5) = 10.293$, $p = .073$. There was no statistically significant interaction between condition and time on cravings for fruit, $F(3,18) = 2.004$, $p = .149$, partial $\eta^2 = .250$. There was also no statistically significant main effect of condition on cravings for fruit, $F(1,6)=3.270$, $p = .121$, partial $\eta^2 = .353$, nor was there a statistically significant main effect of time on cravings for fruit, $F(3,18) = 0.413$, $p = .746$, partial $\eta^2 = .064$.

**Did condition or time impact cravings for vegetables?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on cravings for vegetables. Analysis of studentized residuals showed there were no outliers. All studentized residuals met the normality assumption, as indicated by non-significant Shapiro-Wilk tests of normality ($p > .05$), with the exception of experimental day 1. ANOVA is robust to violations of normality (Schmider et al., 2010) so the ANOVA was still performed. Mauchly's test of sphericity revealed the assumption of sphericity was met for the two-way interaction, $\chi^2(5) = 5.919$, $p = .323$, as well as for the main effect of time, $\chi^2(5) = 2.940$, $p = .715$. There was no statistically significant interaction between condition and time on cravings for vegetables, $F(3,18) = 1.037$, $p = .400$, partial $\eta^2 = .147$. There was also no statistically significant main effect of condition on cravings for vegetables, $F(1,6) = 2.555$, $p = .161$, partial $\eta^2 = .299$. There was a significant main effect of time on craving for vegetables, $F(3,18) = 2.503$, $p = .092$, partial $\eta^2 = .294$. However, pairwise comparisons using Sidak correction did not detect any significant differences among time points (all $p$ values > .10).

**Did condition or time impact cravings for meat?** Yes, there was a significant interaction between condition and time on cravings for meat. A two-way repeated measures

ANOVA was run to determine the effects of condition over time on cravings for meat. Analysis of studentized residuals showed there were no outliers. Half of the studentized residuals violated the normality assumption, with Shapiro-Wilk tests of normality being significant ($p < .05$) for control day 3 and experimental days 1, 2, and 3. Both log transformation and square root transformation were attempted, but as with for cravings for sweets, these transformations increased the number of studentized residuals that were non-normal. Nevertheless, ANOVA is robust to violations of normality (Schmider et al., 2010) so the analyses were run on non-transformed data. Mauchly's test of sphericity revealed the assumption of sphericity was met for the two-way interaction, $\chi^2(5) = 1.950$, $p = .859$, and for the time term, $\chi^2(5) = 9.703$, $p = .090$. There was a statistically significant interaction between condition and time on cravings for meat, $F(3,18) = 1.488$, $p = .089$, partial $\eta^2 = .297$. Consequently, simple main effects were explored using one-way ANOVAs. First, a one-way ANOVA was run on both conditions at each time point to determine the effect of condition on each day. These analyses showed that craving for meat was significantly lower on day 2 of the control week, compared to day 2 of the experimental week, $F(1,6) = 7.149$, $p = .037$, partial $\eta^2 = .544$. However, there were no significant differences in craving for meat on day 1, $F(1,6) = 1.030$, $p = .349$, partial $\eta^2 = .146$, day 3, $F(1,6) = 0.457$, $p = .524$, partial $\eta^2 = .071$, or day 4, $F(1,6) = .007$, $p = .936$, partial $\eta^2 = .001$. Next, a one-way repeated measures ANOVA was conducted to compare the effect of time on craving for meat in the control condition. The time term met the sphericity assumption, as indicated by non-significant Mauchly's test of sphericity, $\chi^2(5) = 1.636$, $p = .899$. Cravings for meat did not significantly change over time in the control condition, $F(3,18) = 1.195$, $p = .340$, partial $\eta^2 = .166$. Lastly, a one-way repeated measures ANOVA was conducted to compare the effect of time on craving for meat in the experimental condition. The time term violated the sphericity assumption, as indicated by a significant Mauchly's test of sphericity, $\chi^2(5)$ = 14.54, $p$ = .014, and consequently the Greenhouse-Geisser correction was used to interpret the results. Cravings for meat did not significantly change over time in the experimental condition, $F(1.614, 9.682) = 2.407$, $p$ = .147, ε = 0.538. These results are shown in Figure 5.

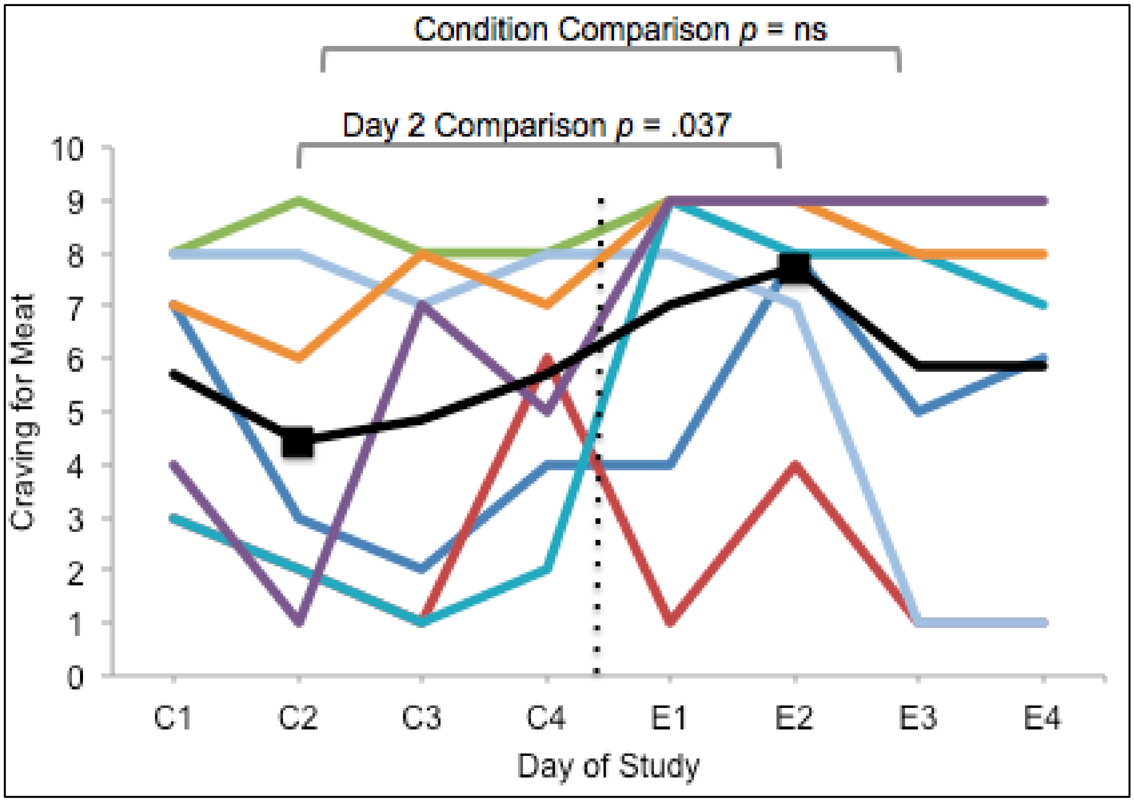


*Figure 5.* Participants' cravings for meat

**Did condition or time impact cravings for dairy?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on cravings for dairy. Analysis of studentized residuals showed there were no outliers. All studentized residuals met the normality assumption, as indicated by non-significant Shapiro-Wilk tests ($p > .05$), with the exception of control day 3 and experimental day 2 and 4. ANOVA is robust to violations of normality (Schmider et al., 2010) so the data were not transformed. Mauchly's test of sphericity revealed that the assumption of sphericity was met for the two-way interaction, $\chi^2(5) = 10.457$, $p = .068$, as well as for the time term, $\chi^2(5) = 6.081$, $p = .307$. There was no statistically significant interaction between condition and time on cravings for dairy, $F(3,18) = 0.971$, $p = .428$, partial $\eta^2 = .139$. There was also no statistically significant main effect of condition on cravings for dairy, $F(1,6) = 1.271$, $p = .303$ partial $\eta^2 = .175$ and no statistically significant main effect of time on cravings for dairy, $F(3,18) = 0.200$, $p = .895$, partial $\eta^2 = .032$.

**Psychological Health**

**Did condition or time impact anger?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on anger. Analysis of studentized residuals showed there were no outliers. A majority of the studentized residuals violated the normality assumption ($p < .05$), as assessed by Shapiro-Wilk tests of normality tests. Both square root and log transformations were attempted (in both cases, a constant of 1 was added to all data points to eliminate 0 values); log transformation on the anger variables resulted in the most normal residuals, and consequently I decided to use log transformation for all mood variables. After log transformation, half of the studentized residuals violated the normality assumption ($p < .05$), as assessed by Shapiro-Wilk tests of normality tests. When the two-way repeated measures ANOVA was re-run on these log transformed variables, the interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 3.392$, $p = .646$. The time term also had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 4.882$, $p = .439$. There was no statistically significant interaction between condition and time on anger, $F(3,18) = .373$, $p = .773$, partial $\eta^2 = .059$. There were also no significant main effects of condition, $F(1,6) = 0.664$, $p = .446$, partial $\eta^2 = .100$, or time on anger, $F(3,18) = 1.307$, $p = .303$, partial $\eta^2 = .179$.

**Did condition or time impact confusion?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on confusion. Analysis of studentized residuals showed there were no outliers. To conform to the transformation of other mood variables, the confusion variables were log transformed (after adding a constant of 1) prior to running the two-way repeated measures ANOVA. All of the studentized residuals continued to violate the normality assumption, as indicated by significant Shapiro-Wilk values ($p < .05$). However, ANOVA is robust to violations of normality (Schmider et al., 2010) and therefore the test was still interpreted. Mauchly's test of sphericity revealed that the assumption of sphericity had been violated for the two-way interaction, $\chi^2(5) = 14.081$, $p = .017$, and consequently the Greenhouse-Geisser method was used for interpreting the interaction. The time variable met the sphericity assumption, as indicated by a non-significant Mauchly's test of sphericity, $\chi^2(5) = 6.006$, $p = .229$. There was no statistically significant interaction between condition and time on confusion, $F(1.250, 7.501) = 0.337$, $p = .627$, $\varepsilon = .417$. There were no statistically significant main effects of condition, $F(1,6) = 1.606$, $p = .252$ partial $\eta^2 = .211$, or time on confusion, $F(3,18) = .393$, $p = .759$, partial $\eta^2 = .062$.

**Did condition or time impact depression?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on depression. Analysis of studentized residuals showed there were no outliers. To conform to the transformation of other mood variables, the variables were log transformed (after adding a constant of 1) prior to running the two-way repeated measures ANOVA. All studentized residuals continued to violate the normality assumption, as indicated by significant Shapiro-Wilk values ($p < .05$), with the exception of experimental day 1. ANOVA on non-transformed data showed the same pattern. However, ANOVA is robust to violations of normality (Schmider et al., 2010) and therefore the test was still interpreted. The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 5.615$, $p = .354$. The time term also had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 2.383$, $p = .798$. There was no statistically significant interaction between condition and time on depression, $F(3,18) = 0.784$, $p = .519$, partial $\eta^2 = .116$. There were also no statistically significant main effects of condition, $F(1,6) = 1.560$, $p = .258$, partial $\eta^2 = .206$, or time on depression, $F(3,18) = 1.216$, $p = .332$, partial $\eta^2 = .169$.

**Did condition or time impact fatigue?** Yes, there was a significant effect of time on fatigue. A two-way repeated measures ANOVA was run to determine the effects of condition over time on fatigue. Analysis of studentized residuals showed there were no outliers. To conform to the transformation of other mood variables, the variables were log transformed (after adding a constant of 1) prior to running the two-way repeated measures ANOVA. The normality assumption was met for all studentized residuals of fatigue, as confirmed by non-significant Shapiro-Wilk values ($p > .05$), with the exception of control day 1. Mauchly's test of sphericity revealed that the assumption of sphericity had been violated for the two-way interaction, $\chi^2(5) = 14.569$, $p = .015$, and consequently the Greenhouse-Geisser method was used for interpreting the interaction. The time variable met the sphericity assumption, as indicated by a non-significant Mauchly's test of sphericity, $\chi^2(5) = 4.651$, $p = .473$. There was no statistically significant interaction between condition and time on fatigue, $F(1.274, 6.371) = 0.928$, $p = .397$, $\varepsilon = .425$. There was also no statistically significant main effect of condition on fatigue, $F(1,6) = 0.154$, $p =$

.711 partial $\eta^2$ = .030. There was a statistically significant main effect of time on fatigue, $F(3,18)$ = 6.348, $p$ = .005, partial $\eta^2$ = .559. Fatigue trended downward across the four time points. Pairwise comparisons using Sidak correction on the transformed data showed that fatigue on day 4 (untransformed $M$ = 4.00, $SE$ = 0.939) was statistically significantly lower than fatigue on day 1 (untransformed $M$ = 6.214, $SE$ = 1.704) by 2.214 points ($p$ = .093) on the 0 to 16-point scale. There were no statistical differences ($p$ values > .10) among the other comparisons.

**Did condition or time impact tension?** Yes, there was a significant effect of time on tension, but none of the subsequent pairwise comparisons were significant. A two-way repeated measures ANOVA was run to determine the effects of condition over time on tension. Analysis of studentized residuals showed there were no outliers. To conform to the transformation of other mood variables, the variables were log transformed (after adding a constant of 1) prior to running the two-way repeated measures ANOVA. The normality assumption was met for a majority of studentized residuals, as confirmed by non-significant Shapiro-Wilk values ($p$ > .05) for all but control day 4 and experimental days 1 and 2. The sphericity assumption was met for the two-way interaction, as confirmed by a non-significant Mauchly's test of sphericity term, $\chi^2(5)$ = 7.915, $p$ = .169. The sphericity assumption was also met for the time term, as confirmed by a non-significant Mauchly's test of sphericity term, $\chi^2(5)$ = 1.881, $p$ = .868. There was no statistically significant interaction between condition and time on tension, $F(3,18)$ = 1.131, $p$ = .363, partial $\eta^2$ = .159. There was also no statistically significant main effect of condition on tension, $F(1,6)$ = 1.285, $p$ = .300 partial $\eta^2$ = .229. There was a statistically significant main effect of time on tension, $F(3,18)$ = 2.516, $p$ = .091, partial $\eta^2$ = .295. Tension was higher on days 2 and 3 than on days 1 and 2. However, pairwise comparisons using Sidak correction showed that none of these values were statistically significantly different from any other (all *p* values $\geq$ .119).

**Did condition or time impact vigor?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on vigor. Analysis of studentized residuals showed there were no outliers. To conform to the transformation of other mood variables, the variables were log transformed (after adding a constant of 1) prior to running the two-way repeated measures ANOVA. All log-transformed studentized residuals met the normality assumption, as confirmed by non-significant Shapiro-Wilk values ($p > .05$), with the exception of control day 3. Mauchly's test of sphericity revealed that the assumption of sphericity had been violated for the two-way interaction, $\chi^2(5) = 11.874$, $p = .043$, and consequently the Greenhouse-Geisser method was used for interpreting the interaction. The time variable met the sphericity assumption, as indicated by a non-significant Mauchly's test of sphericity, $\chi^2(5) = 5.797$, $p = .341$. There was no statistically significant interaction between condition and time on vigor, $F(1.276, 6.379) = 2.963$, $p = .131$, $\varepsilon = .425$. There were also no statistically significant main effects of condition, $F(1, 6) = 0.817$, $p = .407$ partial $\eta^2 = .140$, or time on vigor, $F(3,18) = 1.650$, $p = .220$, partial $\eta^2 = .248$.

**Did condition or time impact social disconnection?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on perceptions of social disconnection. Analysis of studentized residuals showed there were no outliers. All studentized residuals met the normality assumption, as indicated by non-significant Shapiro-Wilk tests of normality ($p > .05$), with the exception of control day 4. ANOVA is robust to violations of normality (Schmider et al., 2010) so the analysis was still interpreted. The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 5.994$, $p = .316$. There was no statistically significant interaction between condition and time on perceptions of social disconnection, $F(3,18) = 1.152$, $p = .355$, partial $\eta^2 = .161$. There was also no significant main effect of condition on perceptions of social disconnection, $F(1,6) = .206$, $p = .664$, partial $\eta^2 = .034$. The sphericity assumption was violated for the main effect of time, $\chi^2(5) = 16.770$, $p = .006$, consequently the Greenhouse-Geisser method was used for interpreting this main effect. There was no main effect of time on perceptions of social disconnection, $F(1.400, 8.402) = .877$, $p = .413$, $\varepsilon = 612$.

**Did condition or time impact perceived stress?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on perceived stress. Analysis of studentized residuals showed there were no outliers. All studentized residuals met the normality assumption, as indicated by non-significant Shapiro-Wilk tests of normality ($p > .05$). The interaction term had sphericity, as confirmed by a non-significant Mauchly's test of sphericity term $\chi^2(5) = 4.998$, $p = .425$, as did the main effect of time, $\chi^2(5) = 3.172$, $p = .679$. There was no statistically significant interaction between condition and time on perceived stress, $F(3,18) = .659$, $p = .558$, partial $\eta^2 = .099$. There were also no significant main effect of condition, $F(1,6) = 1.151$, $p = .325$, partial $\eta^2 = .161$, or of time on perceived stress, $F(3,18) = 2.159$, $p = .128$, partial $\eta^2 = .265$.

### Physical Health

**Did condition or time impact weight?** Yes, weight decreased significantly during the experimental condition, but not during the control condition. A two-way repeated measures ANOVA was run to determine the effects of condition over time on weight. Analysis of studentized residuals showed there were no outliers. Weight met the normality assumption, as confirmed by non-significant Shapiro-Wilk tests of normality ($p > .05$) for all studentized residuals. There was a statistically significant interaction between condition and time on weight, $F(3,18) = 4.254$, $p = .085$, partial $\eta^2 = .415$. Therefore, simple main effects were assessed using one-way ANOVAs. Two one-way ANOVAs were conducted to compare participants' weights across the two conditions on Monday and on Friday. Weight was not statistically different in the control condition ($M = 171.93$, $SD = 26.43$) compared to the experimental condition ($M = 172.47$, $SD = 27.28$) on Monday, $F(1,6) = 0.453$, $p = .526$, partial $\eta^2 = .070$. However, weight was statistically significantly different in the control condition ($M = 171.86$, $SD = 26.76$) compared to the experimental condition ($M = 170.31$, $SD = 26.89$) on Friday, $F(1,6) = 4.184$, $p = .087$, partial $\eta^2 = .411$. During the experimental condition, weight decreased by a mean of 2.157 pounds (95% CI [1.032, 3.282]) from the beginning to the end of the week, a statistically significant amount, $F(1,6) = 22.016$, $p = .003$, partial $\eta^2 = .786$. During the control condition, there was no statistically significant change in weight, $F(1,6) = .010$, $p = .925$, partial $\eta^2 = .002$. So as to provide a more easily interpretable figure, a one-way repeated measures ANOVA was run on weight change scores. There were no outliers, as assessed by inspection of a boxplot. Weight change during the experimental week was normally distributed, as assessed by Shapiro-Wilk's test ($p = .332$), whereas weight during the control week was significantly non-normal ($p = .049$). So as not to impair interpretability, the values were not transformed. Participants lost significantly more weight (a loss of 2.157 pounds) during the experimental week than they did during the control week (a loss of 0.071 pounds; $F(1,6) = 4.254$, $p = .083$, partial $\eta^2 = .415$. These results are shown in Figure 6.

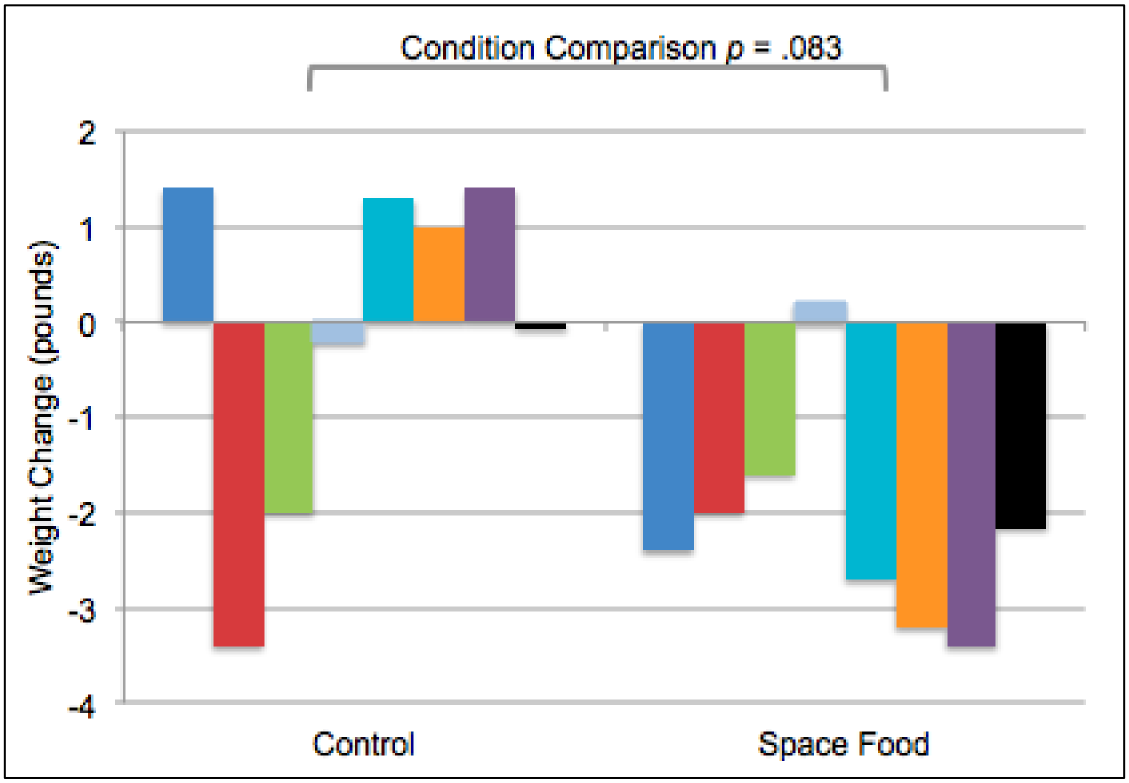


*Figure 6.* Participants' weight change from Monday to Friday

**Did condition or time impact daily self-reported health?** No. A two-way repeated measures ANOVA was run to determine the effects of condition over time on self-reported health. Analysis of studentized residuals showed there were no outliers. The studentized residuals of self-reported health were non-normal, as confirmed by significant Shapiro-Wilk values for all time points (all $p$ values $\leq .020$). However, log transforming the data did not improve this non-normality, and consequently the ANOVA was run on un-transformed data. The interaction term met the sphericity assumption, as assessed by a non-significant Mauchly's test of sphericity, $\chi^2(5) = 4.488$, $p = .490$. The time term also met the sphericity assumption, as assessed by a non-significant Mauchly's test of sphericity, $\chi^2(5) = 3.779$, $p = .589$. There was no statistically significant interaction between condition and time on self-reported health, $F(3,18) =$

1.955, $p$ = .157, partial $\eta^2$ = .246. There were also no statistically significant main effects of condition, $F(1,6)$ = 1.389, $p$ = .283, partial $\eta^2$ = .188, or time on self-reported health, $F(3,18)$ = 0.053, $p$ = .983, partial $\eta^2$ = .009.

**Did condition impact sleep?** No. A one-way repeated measure ANOVA was run to determine the effects of condition on global sleep scores. There were no outliers in the global sleep scores, as assessed by inspection of a boxplot. However, global sleep scores during the experimental week were significantly non-normal, as assessed by Shapiro-Wilk's test ($p$ = .029). Consequently, the global sleep scores were log transformed. After log transformation, there were no extreme outliers, as assessed by inspection of a boxplot for values greater than 3 box-lengths from the edge of the box. The log-transformed global sleep data were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). Sphericity was automatically met, as there were only two time points (Friday of the control condition and Friday of the experimental condition). There were no significant differences between global sleep scores during the control week (untransformed $M$ = 4.43, $SD$ = 2.37) and the experimental week (untransformed $M$ = 3.29, $SD$ = 2.69; $F(1,6)$ = 1.389, $p$ = .283, partial $\eta^2$ = .188.

**Exploratory Analyses Results**

Of the 48 food items that were included in the study (collapsing ratings for the two identical Italian-Style Sandwiches and the two identical Turkey Jerkys, and not including BBQ sauce packets which were not individually rated), the food was rated, on average, $M$ = 5.70 ($SD$ = 1.20). Twenty-four items (50.00%) were rated 6.0 or above, 14 (29.17%) were rated between 5.0 and 5.9, and 10 (20.83%) were rated lower than 5.0. All individual food ratings are shown in Table 10. The implications of these food ratings are expanded upon further in the Discussion.

Table 10 – Individual Food Ratings

| Food | Ratings | | | | |
|---|---|---|---|---|---|
| Item Name | # Ratings | Min | Max | Median | Mean |
| Pineapple Applesauce | 7 | 7 | 9 | 8 | 8.14 |
| Citrus Energy Chews | 4 | 6.5 | 9 | 8 | 7.88 |
| Trail Mix Bar | 3 | 5 | 9 | 8 | 7.33 |
| Berry Applesauce | 7 | 6 | 9 | 7 | 7.29 |
| Chocolate Pudding | 5 | 3 | 9 | 9 | 7.20 |
| PB Chocolate Snack Bar | 5 | 3 | 9 | 8 | 7.00 |
| Blueberry Vanilla Cashew Bar | 3 | 6 | 7 | 7 | 6.67 |
| Hickory Smoked Nut Bar | 5 | 5 | 8 | 7 | 6.60 |
| Lemon Snack Bar | 5 | 4 | 9 | 7 | 6.60 |
| Vanilla Almond Bar | 6 | 2 | 9 | 7 | 6.50 |
| Peanut Butter Protein Bar | 4 | 4 | 8 | 7 | 6.50 |
| Strawberry Yogurt | 6 | 2 | 9 | 7 | 6.33 |
| Oatmeal Raisin Energy Bar | 3 | 5 | 7 | 7 | 6.33 |
| Honey Mustard Nut Bar | 6 | 5 | 8 | 6 | 6.33 |
| Berry Energy Chews | 7 | 3 | 9 | 7 | 6.29 |
| Almond Brownie Snack Bar | 4 | 4 | 7 | 7 | 6.25 |
| Blueberry Turnover | 4 | 5 | 7 | 6.5 | 6.25 |
| Italian-Style Sandwich | 14 | 3 | 9 | 6.5 | 6.21 |
| Cran-Razz Energy Chews | 6 | 3 | 9 | 7 | 6.17 |
| PB Chocolate Chip Meal Bar | 6 | 3 | 8 | 6.5 | 6.17 |
| Strawberry Meal Bar | 6 | 4 | 9 | 6.5 | 6.17 |
| Cookie Dough Snack Bar | 6 | 1 | 8 | 7 | 6.00 |
| Spicy Beef and Cherry Bar | 5 | 1 | 8 | 7 | 6.00 |
| Strawberry Energy Chews | 5 | 2 | 9 | 6 | 6.00 |
| Berry Yogurt | 7 | 4 | 8 | 6 | 5.86 |
| Chocolate Coconut Meal Bar | 6 | 2 | 8 | 6.5 | 5.83 |
| 4oz Beef Jerky+Fruit+Nuts | 7 | 4 | 7 | 6 | 5.71 |
| Bacon Bar | 7 | 1 | 8 | 6 | 5.71 |
| Peanut Butter Cookie Snack Bar | 6 | 3 | 7 | 6.5 | 5.67 |
| Chocolate Energy Bar | 2 | 3 | 8 | 5.5 | 5.50 |
| Punjab Potato Entrée | 7 | 2 | 8 | 6 | 5.43 |
| Carrot Cake Bar | 7 | 2 | 9 | 5 | 5.43 |
| Kung Pao Noodle Entrée | 7 | 3 | 8 | 5 | 5.43 |
| BBQ Beef Sandwich | 6 | 2 | 8 | 6 | 5.33 |
| Vanilla Pudding | 7 | 2 | 8 | 6 | 5.29 |
| Peanut Noodle Entrée | 7 | 2 | 8 | 6 | 5.14 |
| Berry Meal Bar | 7 | 3 | 7 | 5 | 5.14 |
| 2.15oz Turkey Jerky+Fruit+Nuts | 11 | 4 | 8 | 5 | 5.09 |
| Bison and Fruit Bar | 7 | 1 | 8 | 5 | 4.86 |
| French Toast | 7 | 3 | 9 | 4 | 4.86 |
| Pureed Spiced Fruit | 6 | 1 | 9 | 5 | 4.83 |
| Blueberry Yogurt Bar | 6 | 1 | 7 | 5 | 4.33 |
| BBQ Chicken Sandwich | 7 | 1 | 9 | 4 | 4.29 |
| 2.15oz Beef Jerky+Fruit+Nuts | 5 | 2 | 7 | 4 | 4.00 |
| Cherry Turnover | 6 | 1 | 8 | 3.5 | 4.00 |
| Strawberry Kiwi Energy Gel | 3 | 3 | 4 | 3 | 3.33 |
| Nut Butter Protein Bar | 3 | 1 | 4 | 2 | 2.33 |
| Cacao Banana Protein Bar | 5 | 1 | 4 | 2 | 2.20 |

**Qualitative Results**

Participants were given the opportunity to provide qualitative feedback each day of the study. Participants were also interviewed post-study, which is where the richest qualitative data were obtained. From participants' responses, it became clear that participants wanted to see less of certain food items and more of other items. Table 11 summarizes participants' most liked and disliked foods. Table 12 summarizes participants' suggestions on how to improve the experimental diet.

Table 11 – Qualitative Descriptions of Most Well-Liked and Most Disliked Foods

| | |
|---|---|
| **Most Well-Liked Foods** | |
| Applesauce & Yogurt | Every participant (N = 7) reported liking “moist” food, especially the applesauce and yogurt. Yogurt was more controversial than applesauce, with no participant reporting a dislike of the applesauce and a minority of participants reporting a dislike of the yogurt. |
| Meat Bars | Many participants enjoyed the meat bars. Only two participants reported disliking the texture of the bars. |
| Energy Chews | Most participants liked the Energy Chews, despite also expressing a preference for fewer “unintentional desserts” (e.g., sugary bars). |
| Nut Bars | Nut bars were frequently mentioned as the best of the bars, with both the sweet and the savory nut bars being generally well liked. |
| **Most Controversial Foods** | |
| Pudding | Despite the strong preference for more moist foods in pouches, the pudding pouches received mixed reviews. Some loved the pudding, whereas others reported, “[T]he pudding was gross. Like really gross.” |
| Noodle and Potato Entrées | Some participants said the Noodle and Potato Entrées were their favorite, whereas others said the Noodle Entrées had a strange texture and the Potato Entrée was among their least favorite foods. |
| Meat Sandwiches | Meat sandwiches were controversial, with three participants mentioning them among their most favorite items and three participants mentioning them among their least favorite items. |
| French Toast | Two participants thoroughly enjoyed having the French Toast for breakfast. However, the rest of the participants did not seem to enjoy either the French Toast or the Turnovers. |
| **Most Disliked Foods** | |
| Sugary Bars | Participants disliked the high number of foods that were sugary without being intentional desserts (e.g., Nut Butter Protein Bar, Blueberry Yogurt Bar). Participants expressed a strong desire for more low-sugar entrées, as well as a moderate preference for more “intentional” desserts that could be eaten at the end of meals to assist with satiation. |
| Jerky+Fruit+Nuts | Participants disliked the jerky’s toughness, and that fruit and nuts were mixed in with meat. They wanted softer, larger-pieced jerky on its own (especially salty, peppered jerky), with fruit served separately. |

Table 12 – Participants' Desired Changes to the Diet

| | |
|---|---|
| **Provide Entrée, Side Dish, & Dessert** | Participants reported the desire for a beginning, middle, and end to a dish. They wanted to see a main dish that contained meat, a side dish of vegetables, and a dessert at the end, so that they could feel like they were eating a real meal instead of tiny snacks. As one participant said, she wanted a dessert "…not for a nutritional reason but for a mental reason, like an entrée, a side, and a dessert." Another participant said, "As someone who has a sweet tooth, I enjoy my meals when they are complete. Thinking like a main, a side, and a dessert." |
| **Add Treats** | Participants wanted something to look forward to. As one participant reported, "When you hit the monotony of the [energy bars], having one tiny little treat at the end of the day helps a lot. Like a [hard candy] or a . . . piece of candy that lasts a long time in space." |
| **Add Protein** | Participants wanted to see more animal protein, such as jerkies without fruit and nuts. In particular, they wanted to see jerky that was more tender and salty, and with larger (not bite size) pieces. One participant wanted "Anything salty. More beef jerky. Maybe even just peppered jerky." The desire for more protein seemed to stem from both a craving for salt and a craving for meals. As one participant said, "[protein] can have a kind of placebo effect on you, have you feel like you're eating real food." No participants reported craving nuts, but one participant said they would be open to eating "nuts without the sugar." |
| **Add Vegetables & Fruit** | Participants wanted to see more vegetables and fruit, even if the food was dehydrated. Suggestions included: kale chips, plantain chips, and fruit leathers. |
| **Add Salt** | Participants wanted more salt and less sugar. Suggestions included salted jerky and potato chips. |
| **Add Condiments** | Several participants expressed a desire for more condiments that would have allowed them to customize meals. Suggested condiments included ketchup, mustard, and hot sauce. One participant reported that having the BBQ sauce made his day. |
| **Don't Rely on Meal Replacements** | Participants were explicitly asked if they would have preferred meal replacement drinks. Only one participant thought that meal replacement drinks "would have been cool psychologically" because it would provide balanced meals, and another participant said that meal replacement drinks sounded "kind of easier." However, all but one participant said they preferred eating real food. As one said, "I would not want to have a liquid diet. Especially because I can't imagine there would be much variety with it so I imagine I would get sick of it very fast." Another said he was not a fan of soy, "so if I had to drink [a soy-based meal replacement drink] for a week I think I would have been less |

| | |
|---|---|
| | than stoked about it." One other participant said, "I tried [a soy-based meal replacement drink]. It's very depressing after a few days." |
| **Add Newly-Released Foods** | New food options are continually arriving on store shelves. When I showed participants images of some newly-released entrées that contained spicy meats, they expressed an interest in trying these foods in future versions of the diet. |
| **Get Astronauts Used to the Diet Before Flight** | Several participants commented that the experimental diet became easier, not harder, over time. One participant reported finally just resigning to the fact that this was what he had to eat. Yet another participant reported that, "At the start I didn't change much [pick and choose what to eat] because I was overwhelmed by the choices . . . in the second half of the week . . . I was able to rearrange things into that kind of a structure [of having an entrée, a side, and a dessert]. Yesterday for lunch I had a BBQ sandwich, one of the protein bars as a side, and then the pudding packet as a dessert and that felt complete. That was one of my happiest meals . . . whenever I had that kind of structure to it, it felt better. Same goes for the first day's breakfast. I started really strong with that. It was the French Toast, the yogurt… it felt well rounded. It had a beginning, a middle, and end." |

**Comfort foods.** When asked "What would you like to eat if you were having a bad day?" participants reported they would want the applesauce (N = 3), meat bars (N = 2), snack bars (N = 2), nut bars (N = 2), chocolate pudding (N = 2), yogurt (N = 1), energy chews (N = 1), beef jerky (N = 1), and noodles (N =1).

**Participants did not avoid foods.** Every participant said they did not avoid certain foods, even if they did not expect to like the foods. For instance, a participant who knew he did not like coconut still tasted and rated the Chocolate Coconut Meal Bar. Additionally, a participant who knew she did not like bananas still tried the Cacao Banana Protein Bar. However, some participants found they could not try all the different food items because they "just didn't have the appetite for that."

**Diet may be acceptable for short-duration flights.** When asked if they would have minded eating this food in a Crew Transportation Vehicle, all participants said they didn't think they would have minded. The reasons for this were threefold. First, they'd be in outer space and they'd be "stoked" about that. Second, the food experience would be shared and they could use food as currency to trade: "everyone would be eating the same thing . . . You could trade, too." Third, there would be no other food options: "I would know this is what I'm getting and there are no other options." Consequently, the diet used in this study may be acceptable for short-duration flights, such as in a Crew Transportation Vehicle.

**Adhering to the diet was challenging, but enjoyable.** When asked if they regretted participating in the study, no participant reported regrets. Instead, they reported, "I had a blast… I had a lot of fun. It was great. It felt like an adventure, trying new food. . . I would definitely buy those [some of the food she ate in the study] for my next camping trip." Even participants who said the study was more difficult than they had expected reported they did not regret participating. As one participant said, "I just like trying new things and learning more about myself and how I react to them . . . Adversity is a good thing in small amounts and it's a good story."

### ***Post Hoc* Results**

One participant was excluded from all *post hoc* analyses due to not recording fluid intake. Therefore, for all analyses described in this section, N = 6. Participants' percent of calories from protein, fat, and carbohydrates are shown in Figure 7.

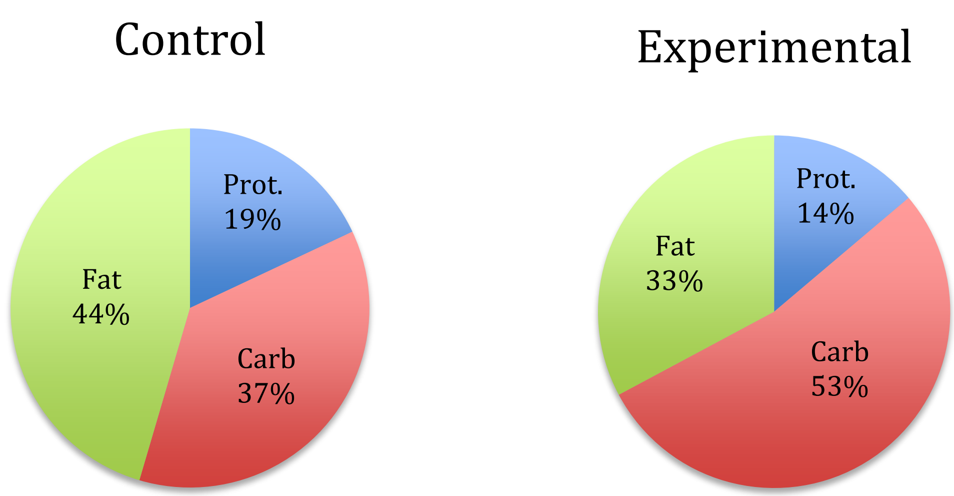


*Figure 7*. Participants' percent of calories from protein, fat, and carbohydrates

These participants ate approximately 1,926 calories per day in the control condition and 1,911 calories per day in the experimental condition. Consequently, each day of the control condition, they consumed approximately 91 grams of protein, 178 grams of carbohydrate, and 94 grams of fat, resulting in an average total macronutrient consumption of 363 grams a day. Each day of the experimental condition, they consumed approximately 67 grams of protein, 253 grams of carbohydrate, and 70 grams of fat, resulting in an average total macronutrient consumption of 390 grams a day. By these calculations, participants in the experimental condition ate approximately 27 more grams from protein, carbohydrates, and fat, combined, each day.

After adding in self-reported fluid intake, these participants consumed an average of 3,180.42 grams (7.01 pounds) of food and fluid each day of the control condition, and an average of 2,800.82 grams (6.17 pounds) of food and fluid each day of the experimental condition.

# Discussion

## Summary of Findings

The primary aims of this study were to investigate the impact of a possible commercial space food diet on (a) nutrient intake, (b) food satisfaction, (c) psychological health, and (d) physical health. These aims were investigated by having a sample of aerospace employees eat a diet of commercial, ready-to-eat food for four days one week, and comparing their outcomes to when they ate essentially as normal for four days another week.

The seven employees that participated in this study were an ideal sample, given that they had a high workload (reflecting the high workload of future commercial astronauts) and represented the type of space enthusiast that will likely seek out commercial space flights, once they become more readily available. These employees had relatively ordinary eating habits and average personalities, being just slightly more extraverted and emotionally stable than a normed sample. Their adherence to the study was extremely high, largely driven by their desire to contribute to the future of space food.

**Nutrient intake.** The experimental diet was designed to meet nearly all nutrient recommendations set forth by NASA and to be highly satisfying. Consequently, I had hypothesized that while in the experimental condition, participants would consume the same amount of calories as they did while in the control condition. I had also hypothesized that there would be no significant decline in caloric intake across the four days of each condition. The results of this study coincided with these hypotheses. When caloric intake was computed based on participants' self-reported food intake, there was no significant difference in caloric intake between conditions and no significant change in caloric intake over time.

**Food satisfaction.** Although the experimental diet was designed to be highly satisfying, it was nevertheless made entirely of commercial, ready-to-eat food. Consequently, I had hypothesized that while in the experimental condition, participants would rate the food as being slightly less hedonically rewarding and slightly more monotonous, with "slightly" being defined as less than 2-point decreases on the 9-point scales assessing hedonic food ratings and satisfaction with variety. In line with these hypotheses, the experimental food, as compared to the control food, was rated 1.345 points lower on the hedonic food rating scale and 1.750 points lower on the scale assessing satisfaction with variety. In both instances, these differences between conditions were statistically significant ($p$ values $\leq .011$). Consequently, as predicted, the experimental diet was rated as being slightly less hedonically rewarding and slightly more monotonous.

I had also hypothesized there would be no significant decline in food satisfaction over the four days. In line with this hypothesis, there was no significant interaction between condition or time and no significant main effect of time on either hedonic food ratings or on satisfaction with variety. Thus, although participants rated the experimental diet as being slightly less hedonically rewarding and slightly more monotonous, the diet did not become less rewarding or more monotonous over time.

Because the diet was comprised of long shelf-life, ready-to-eat food, it contained few vegetables and was a relatively sweet, salty diet. Consequently, I had hypothesized that during the experimental condition, as compared to during the control condition, participants would show higher cravings for vegetables, lower cravings for salty food, and lower cravings for sweets. The results showed that, in line with the hypothesis regarding sweets, participants reported lower cravings for sweets (0.82 points lower on the 9-point scale) while in the experimental condition. Participants' comments in the post-study interviews further verified a reduced craving for sweet foods. However, contrary to my hypotheses regarding cravings for vegetables and salt, there were no significant differences between conditions on cravings for vegetables or salt. In post-study interviews, some participants reported they would have liked to have seen more vegetables and more salty food.

Unexpectedly, there was a significant interaction between condition and time on cravings for meat, with participants in the experimental condition craving meat significantly more than participants in the control condition on day 2. Although cravings for meat were not significantly different on the other days of the week, this significant result coincides with participants' qualitative feedback that they would have liked to have seen more meat in the experimental condition.

**Psychological health.** The experimental condition was designed to be nutritious and highly satisfying, and was therefore expected to meet participants' psychological needs. Consequently, I had hypothesized that while in the experimental condition, participants would show psychological health that was equivalent to their psychological health while in the control condition, as indicated by no significant differences in mood, perceptions of social disconnection, and perceived stress.  I also hypothesized there would be no significant decline in psychological health over the four days, as indicated by non-significant time by interaction terms. In line with these hypotheses, participants showed no significant differences in perceptions of social disconnection, perceived stress, or mood between conditions. There were also no significant differences in perceptions of social disconnection or perceived stress over time. The only mood that changed significantly over time was fatigue; participants reported being less fatigued on the fourth day of each week than they were on the first day of each week. The time term was also significant for the mood of vigor, however pairwise comparisons showed no significant differences on any particular day. Thus, there was no significant decline in psychological health over the four days.

**Physical health.** The experimental diet was designed to be nutritious, and I had anticipated participants would consume equivalent calories in both the experimental and control conditions. Consequently, I had hypothesized that while in the experimental condition, participants would have physical health that was equivalent to their health while in the control condition, as indicated by no significant differences in sleep or self-reported health and no significant weight loss. I also hypothesized there would be no significant change in self-reported health or weight over time. In line with my hypotheses for sleep and self-reported health, participants showed no significant differences in global sleep scores or self-reported health between conditions, and no significant decline in self-reported health over time. However, contrary to my hypothesis for weight, participants in the experimental condition lost significantly more weight than participants in the control condition. In the control condition, participants lost just 0.071 pounds from Monday to Friday, a change that was not significant. Conversely, in the experimental condition, participants lost 2.157 pounds from Monday to Friday, a change that was statistically significant.

Why did participants lose more weight in the experimental condition if they didn't eat fewer calories? There are many possible explanations. It is possible that participants lost fat mass or lean mass due to eating less in the experimental condition. However, given that there were no significant differences in caloric intake between the two conditions, and that my visual checks of the leftovers showed that participants accurately reported their food intake, this is unlikely. Participants were not asked to record their exercise, and consequently, it is possible that participants exercised more during the experimental week, resulting in weight loss. However, there were no significant differences in vigor or fatigue between the two conditions, and consequently this is also considered unlikely.

The explanation that I find most likely is a reduction in water intake. Weight loss can indicate a reduction in fat mass or lean mass, but it can also indicate a reduction in water mass, or dehydration. The food in the experimental condition was purposely designed to provide sufficient calories while being lower in mass and volume than everyday food. One of the best ways to create energy-dense food is to reduce water content (another way is to reduce air content). Consequently, the food in the experimental condition had lower water content than the food in the control condition. It is therefore likely that participants consumed less water from food during the experimental condition, and that they did not sufficiently make up for this difference by drinking more fluids. This hypothesis is supported by the results of the *post hoc* analyses, described below.

***Post hoc* water analyses.** In the *post hoc* analyses, it was found that participants in the experimental condition reported consuming 2,800.82 total grams of food + fluid each day, whereas participants in the control condition reported consuming 3,180.42 total grams of food + fluid each day. Therefore, participants in the experimental condition reported consuming an average of 379.6 grams (0.84 pounds) less over the course of a day, even though they did not consume fewer macronutrients (protein, carbohydrates, and fat). Aside from macronutrients, the weight of food usually results from a substantial amount of water and a small amount of fiber and alcohol, along with a relatively small amount of ash (the ash content is usually less than 5% for fresh food and less than 12% for processed food; McClements, n.d.). Consequently, it appears likely that participants in the experimental condition consumed less water. This would not be surprising, given that the experimental food was designed to be energy dense.

In support of this theory, participants in the experimental condition lost an average of 2.157 pounds, or 1.25% of their body weight, which can easily occur from dehydration. Some researchers have defined mild dehydration as a 1-2% decrease in body weight, moderate dehydration as a 2-5% decrease in body weight, and severe dehydration as a 5% or greater decrease in body weight (Szinnai, Schachinger, Arnaud, Linder, & Keller, 2005). It is possible that during the experimental condition, participants consumed less water from food and fluids, resulting in mild dehydration that contributed a 1.25% decrease in body weight. For comparison, when participants were in the control condition they lost 0.04% of their body weight.

If participants were, indeed, mildly dehydrated during the experimental condition, is this a cause for concern? During the experimental condition, participants consumed approximately 2,410.82 grams from non-energy-yielding sources (i.e., from water, ash, and fiber). Even if the ash and fiber comprised 15% of this mass, participants would have consumed over 2,000 grams of water – the minimum intake required by NASA, based on participants' average caloric intake in this study (see Table 1). Additionally, decrements in cognitive or physical performance usually do not occur until individuals have lost 2% or more of their body weight (Grandjean & Grandjean, 2007). Indeed, during the experimental condition, participants showed no significant changes in psychological or physical outcomes other than decreased weight. These factors would indicate that any mild dehydration experienced by participants is little cause for concern.

However, although NASA's ISS requirements stipulate astronauts should receive at least 2 liters of water a day, the Institute of Medicine recommends more than that (Institute of Medicine, 2005b). Furthermore, numerous factors make it impossible to determine whether sufficient water was consumed in the experimental condition: participants' fluid reports were questionable, participants were allowed to consume caffeine, and participants did not record their exercise. Nevertheless, at present, the data do not indicate participants were worrisomely dehydrated while eating the experimental diet. In future studies of commercial space food, incorporating measures that can differentiate between fat mass and lean mass (e.g., dual-energy x-ray absorptiometry [DXA] scans) and measures that can assess changes in dehydration (e.g., directional changes in bioelectrical impedance vectors; Heavens, Charkoudian, O'Brien, Kenefick, Cheuvront, 2016) would help to determine the cause of weight loss.

**Macronutrient proportions.** NASA's ISS requirement is that astronauts be provided with 12-15% of their calories from protein, 30-35% of their calories from fat, and 50-55% of their calories from carbohydrates (Smith et al., 2009). The Institute of Medicine (2005a) sets forth adequate macronutrient proportions of 10-35% of calories from protein, 25-35% of calories from fat, and 45-65% of calories from carbohydrate. During the experimental condition, participants met both NASA and the Institute of Medicine's recommended macronutrient proportions. During the control condition, participants exceeded NASA's protein and fat requirements, and failed to meet the lower limit of NASA's carbohydrate requirement. During the control condition, participants also consumed fat in excess of the Institute of Medicine's recommendations. In summary, during the experimental condition, participants consumed macronutrients in the recommended proportions, whereas during the control condition they did not.

## Recommended Changes to the Diet Based on Participant Feedback

Qualitative interviews with participants revealed that they wanted to see more animal protein, more vegetables and fruit, more "intentional" desserts, and fewer sweet energy bars. Ways in which these items could be added to the diet are explained below.

**Protein.** Participants expressed a desire for more animal protein, indicating that satisfaction with the diet may increase if more animal protein were added. Increasing the amount of animal protein in the diet could also assist with assembling a low fiber diet, which I aimed to achieve (so as to prevent the need to use the toilet during transport) but which was difficult to attain, as many “healthy” prepackaged foods are high in fiber.

Increasing the amount of protein in the experimental diet would not necessarily be unhealthy, as 14.5% of calories in the diet came from protein, and the Institute of Medicine’s upper limit for protein is 35% (Institute of Medicine, 2005a). However, NASA has an upper limit of 15% because a high protein diet, especially one from animal sources, could lead to hypercalcemia and increased risk of developing renal stones (Smith et al., 1999; Tracy et al., 2014). Renal stones are especially a concern for astronauts as physiological changes during spaceflight may already lead to increased risk of renal stone formation (Pietrzyk, Jones, Sams, & Whitson, 2007). Consequently, there is rationale for keeping protein intake relatively low.

As discussed in Table 1, given that many of the foods in the experimental diet contained a mix of animal and vegetable proteins, and that I did not have access to a calorimeter, it was not possible for me to calculate the experimental diet’s percentage of protein from animal vs. vegetable sources. However, based on a visual analysis of the types of food in the experimental diet, it is possible that diet did not meet NASA’s recommendation to have 2/3 of protein come from animal sources (Smith et al., 2009). It therefore seems advisable to at least shift away from plant-based protein bars and toward more substantial animal sources, such as peppered beef jerky. Various brands and varieties should be investigated to identify a meat source that is tender, salty, spicy, and substantial enough to provide a “meal-like” sensation, without exceeding the sodium limit and without having small pieces that could flake off and float away in a microgravity environment.

**Vegetables and fruit.** Participants frequently reported desiring real vegetables and fruit. Adding dried vegetables and fruits is therefore strongly advised. Various vendors sell dried vegetable and fruit packs, and compressed fruit bars have previously been flown on the International Space Station. Various other options exist and are worthy of exploration.

**Intentional desserts.** Participants wanted to see more desserts that were intentionally a dessert, as opposed to an energy bar that tasted like a dessert. An occasional candy treat, such as hard candies or chocolate candies, could therefore be considered.

### Recommended Changes to the Diet Based on Food Ratings

NASA only includes items that score, on average, 6.0 or higher on the 9-point Hedonic Scale. In this study, participants rated 50% of the experimental diet items as 6.0 or higher. Because these items were so well liked, I recommend keeping these items in the diet. See all green-colored items in Table 10 for a list of these foods.

Nearly one-third (29.17%) of the items in the experimental diet were rated between 5.0 and 5.9. These foods were rated below NASA's acceptable score of 6.0 and their elimination should therefore be considered. However, it's not clear that participants' ratings in this study were equivalent to NASA's food ratings because in this study, participants ate and rated the food in a naturalistic setting, rather than in a laboratory. Research has shown that the environment can greatly impact food ratings; individuals rate food differently depending upon whether they are in a laboratory, a restaurant, or a cafeteria (King, Meiselman, Hottenstein, Work, & Cronk, 2007; Meiselman, 2006). In this study, participants may have eaten in the cafeteria with colleagues, alone at their desk, or at home. Sometimes, when they ate, they saw just their own food, and at other times they saw a plethora of freshly prepared food that their colleagues were eating, yet which they could not eat. Consequently, it is not clear how the multiple environments in this study should be categorized and how participants' ratings would have been different, had they been doing a taste test in a laboratory.

Furthermore, some items that received a mean rating between 5.0 and 5.9 were controversial, meaning that some participants loved them and some hated them. Consequently, when designing future versions of the experimental diet, I recommend that these 5.0- to 5.9-scored items be put back into the pool of options for consideration. Instead of eliminating all these items, perhaps reducing their frequency would be wiser. For instance, all three noodle/potato entrées received mean ratings between 5.0 and 5.9. Yet one participant specifically requested more of these items, indicating a strong preference for them. Keeping just one noodle entrée in the menu may be a better choice than eliminating them completely.

However, eliminating all 10 items that were rated lower than 5.0 is advised. Because participants were provided with over 3,000 calories a day, these 10 items could be completely removed from the diet while still providing over 2,400 calories per day – well over the 1,810.71 calories that participants, on average, consumed each day of the experimental condition. Removing these 10 items from the diet would still provide crew with 38 different food items for their 4-day trip and would, if the ratings for the remaining food items did not change, raise the mean food rating of the diet to 6.18 on the Hedonic Scale.

**Recommended Changes to the Diet Based on Researcher's Experience**

**Remove odiferous food items.** All experimental food had to be eaten at room temperature. Room temperature food is less odiferous than heated food, and I had therefore anticipated the smell of food would not be a strong factor in food choice. Consequently, participants were not asked to rate the smell of foods. However, the strong odor of certain foods became apparent to me while evaluating leftovers. This experience highlighted a major difference between the study environment and the Crew Transportation Vehicle: in the study, the open-air setting likely muted the smell of foods, whereas in the enclosed Crew Transportation Vehicle, the smell of foods would be easily noticeable. This is a concern because smells could exacerbate the symptoms of space motion sickness, which is commonly experienced by astronauts during early flight. Former astronauts have recalled that, "Even if the sick people wisely stuck to broth and crackers, odors from the meals being enjoyed by those fortunate enough to feel better could be overwhelming. Some commanders made the law of 'no stinky food on day 1 or 2.' That precluded such odiferous items as tuna, salmon, or beef with barbeque sauce" (Kerwin & Seddon, 2002, p. 924). It would therefore be wise to remove strongly odiferous foods from the diet. The odor of foods could be evaluated in the same way that materials used in spaceflight are evaluated, by having panelists rate the smell from 0 = "undetectable" to 4 = "revolting" (NASA technical standard NASA-STD-6001A; NASA, 2008). Foods that are rated 2.5 (between "easily detectable" and "objectionable") or higher could be eliminated from the diet (Clément, 2011; NASA, 2008).

**Allow for personalization.** Another factor that became quickly apparent was the large variation in participants' food preferences. Some participants craved the noodle entrées whereas others said the noodles were inedible. Humans show large variation in food preferences and food choices. Food choice is impacted by not only the qualities of the food itself, but also demographic (age, gender), sociocultural, and economic variables (Drewnowski, 1997).

When NASA initially designed the Space Shuttle menu, a standard menu was developed for all missions (Perchonok & Bourland, 2002). After four missions, the menu was changed to be crew-selected, so that crew could provide input but all crewmembers were ultimately provided with the same food. However, crewmembers expressed a desire for even more personalized menus, and consequently starting with the seventh Space Shuttle mission (STS-7), individualized menus were provided for each crewmember. Crewmembers were allowed to select the food they wanted from a menu of over 350 food items. Crewmembers' choices were then analyzed by a dietitian, who would recommend substitutions to obtain a balanced diet.

Based on the large variation in food preferences observed in this study, it seems the individualized menu would be better for achieving high food satisfaction than the standard menu. However, most commercial aerospace companies hope to fly not just eight astronauts a year, but hundreds. Personalizing the diet for each astronaut could become onerous. Instead, I recommend letting crewmembers pick the food they want from a collection of 100+ food items. Each crewmember could be provided with a container (which would be sized to fit their food storage unit in the Crew Transportation Vehicle) and be allowed to select whatever food they wanted as long as it fit in that container and met certain mass restrictions. Crewmembers could taste the food before making their selections. As mentioned before, taste testing the food ahead of time could promote greater food satisfaction by getting crewmembers accustomed to the food. However, they should be reminded that in the spacecraft, they may experience digestive discomfort and they may therefore want to select foods that would calm their stomachs. After crewmembers make their food choices, a dietitian could evaluate their food choices and provide feedback. For instance, the dietitian could inform crewmembers that the items they selected are high in fiber or sodium and it would be advisable to choose some lower fiber or lower sodium options. The dietitian could also aid crewmembers in selecting a diet that contains main dishes, side dishes, and desserts – a structure that many study participants reported craving. Sample breakfasts, lunches, and dinners could be provided to guide crewmembers in making their food choices.

This “pick your meals” approach may help increase food satisfaction while keeping the burden on aerospace companies low. However, this strategy should be tested prior to implementation because there is also the risk that providing crewmembers with such a vast number of food choices could lead them to become overwhelmed and less, not more, satisfied. Researchers have found that having numerous options can lead some people to experience regret and decreased satisfaction (Schwartz et al., 2002). In one experimental study (Osdoba, Mann, Redden, & Vickers, 2015) having no choice in what one was served was shown to reduce anxiety and blood pressure more than being able to choose one’s meal components. If the “pick your meals” approach resulted in lower, not higher, food satisfaction, a middle-ground strategy might involve providing crewmembers with 10 breakfast options and 20 lunch and dinner options, and allowing them to taste test and select which meals they want. Another simple tactic that could increase food satisfaction would be to let crewmembers pack their favorite candies for dessert.

Allowing crewmembers to choose their own food would enable them to make the calculated decision regarding whether they wanted the most calorie-dense food (to fit the greatest number of calories in the space with which they were provided) or whether they wanted less energy-dense food, which would result in fewer calories but perhaps higher food satisfaction. For instance, one participant who ate relatively few calories per day reported desiring lower energy density foods such as crackers, yogurt, and dehydrated vegetables and fruit. This participant also reported craving tuna, which is an item I did not include in the diet because the packaging on pouched tuna is higher mass and higher volume than the plastic overwrap on jerky. However, this individual had no need for 3,000 calories a day, and therefore no need for the most energy-dense foods. If she were provided with the same sized food container as her fellows, she would be able to fit her preferred foods in that container (or comparable yet less-odiferous foods, such as pouched chicken), despite their lower energy density, while still meeting her nutritional needs.

It is possible that, if taking this approach, some crewmembers may underestimate how much food they will want to eat. However, this would not likely be a problem in the Crew Transportation Vehicle, as food intake would likely be severely suppressed due to space motion sickness. Nearly half of all astronauts experience space motion sickness during the first eight to 72 hours of spaceflight, resulting in periodic (every few hours) bouts of projectile vomiting (Thornton & Bonato, 2013) and avoidance of food (Kerwin & Seddon, 2002). Food intake would also likely be suppressed due to being busy with more pressing tasks. Astronauts have recounted that, "At lift-off, astronauts knew the food system well, but eating was not high on the list of priorities during the hectic hours of getting to orbit and beginning on-orbit operations" (Kerwin & Seddon, 2002, p. 924). Thus, if individuals were allowed to choose their own meals, they would likely have sufficient food in the Crew Transportation Vehicle. Allowing individuals to choose their preferred foods may also prevent food from going uneaten, which could prevent the flight of unnecessary mass and volume.

**Provide short shelf-life foods.** When restricted to eating entirely shelf-stable, packaged foods, the participants in this study craved fresh foods. NASA astronauts also experience these cravings, which is why NASA has, since the Shuttle era, flown small quantities of fresh fruit (e.g., oranges, apples) and fresh vegetables (e.g., garlic, onions, carrot sticks; Smith et al., 2009). Astronauts must eat these fresh foods in a relatively short period of time, but given that astronauts crave such items, this is not a problem. Providing carrot sticks, apples, snap peas, and other fresh fruits and vegetables in the Crew Transportation Vehicle should therefore be considered.

## Summary of Recommendations

The recommendations that were described at length above are summarized below:

1. Remove all items rated lower than 5.0 on the Hedonic Scale.
2. Reconsider all items rated between 5.0 and 5.9 on the Hedonic Scale, along with newly-released and participant-recommended foods.
3. Replace some plant-based proteins with animal proteins that are tender, salty, spicy, and substantial enough to provide a "meal-like" sensation (e.g., peppered beef jerky).
4. Add dehydrated fruits and vegetables (e.g., freeze-dried peas, compressed fruit bars, dehydrated bananas).
5. Add fresh fruit and vegetables.
6. Add intentional desserts (e.g., hard candies).
7. Assemble these foods into meal-like structures with entrées, sides, and desserts.
8. Remove strongly odiferous foods.
9. Allow crewmembers to taste the food ahead of time.

10. Allow crewmembers to choose their own food.

## Strengths and Limitations

This study had numerous methodological strengths. First, the study used a sample of commercial aerospace employees who were interested in participating in future commercial spaceflight opportunities and who may represent the future of commercial astronauts. Consequently, they were an ideal sample for a study of commercial space food. The study design was also novel; although numerous “space food taste tests” and nutritional studies of astronauts have been conducted (Altman & Fisher, 1986; Perchonok & Bourland, 2002; Weiss, 1969), and although researchers have investigated the health impact of eating at commercial restaurants (Ries, Kline, & Weaver, 1987) and of eating ready-made meals (e.g., fast-food; Alkerwi, Crichton, & Hébert, 2015), researchers had not previously investigated the psychological and physical health consequences of eating commercially prepackaged (yet not low-calorie or diet) ready-to-eat food for several days. Hence, this was the first evaluation of the psychological and physical impact of eating commercial, ready-to-eat “space food” for the length of time that astronauts could be in the Crew Transportation Vehicle.

However, the study was not without limitations. One limitation is that the consequences of eating the experimental diet cannot be directly compared to the consequences of eating NASA space food. However, NASA space food is not commercially available, and therefore it was not possible to obtain NASA space food for use in this study. Furthermore, many of the individuals who will participate in commercial spaceflight will be civilians, rather than NASA employees, and such civilians would not have the option of eating NASA-made food. Consequently, this study’s comparison of commercial, ready-to-eat food to eating as normal was the best possible method for investigating the study’s aims.

Another limitation of this study is that participants were permitted caffeinated coffee and tea throughout the experimental condition, whereas astronauts will not have access to these caffeinated drinks while in the Crew Transportation Vehicle. However, asking participants to refrain from consuming caffeine would have increased the burden of participating in the study. Additionally, because this study used a parallel crossover design, in which participants served as their own controls, it is likely that participants’ caffeine consumption was similar in both the experimental and control conditions. This similar caffeine consumption would effectively cancel out the possible effect of caffeine on study outcomes. Furthermore, astronauts in the Crew Transportation Vehicle will likely have access to caffeine or alertness-enhancing medications – both of which are used on the ISS (Wotring, 2015) – which could be used in the event that enhanced or extended alertness is required. Consequently, allowing caffeinated drinks in this study should not have greatly impaired the generalizability of the results.

Another limitation is that participants in the experimental condition may have altered the timing of their meals, ate in a different location, or ate with different people than usual. These factors could have influenced participant outcomes in unknown ways. However, forcing participants to eat at exactly the same times as usual was not feasible. For instance, some participants ate meals at different times every day. Forcing participants to eat in certain ways or to eat certain amounts could have also led to resistance, as was seen when researchers attempted to get all astronauts on a Skylab flight to eat the same amount (Kerwin & Seddon, 2002).

Consequently, participants were encouraged, rather than required, to eat with the same people, at the same time, and in the same location as usual.

Another limitation of this study is the small sample size. However, the study used a parallel crossover design, which is a study design that can obtain greater power with smaller sample sizes, as compared to a parallel-group design (Wellek & Blettner, 2012). The study also used repeated measures, with most of the measures being completed eight times throughout the study. These repeated measures further increased the study's power (Marshall, Scarbro, Shetterly, & Jones, 1998). Additionally, the study used continuous, as opposed to binomial, dependent variables, which also increased power. Finally, I conducted *a priori* power analyses, which indicated a sample size of six would be sufficient for the effect magnitudes I aimed to detect, and I ended up with a sample size of seven. Consequently, the sample size of this study was sufficient to detect any meaningful differences between the two conditions.

Another limitation of this study is that it took place on Earth in normal-gravity conditions, and therefore it is not a perfect predictor of how astronauts will eat while in the Crew Transportation Vehicle. For instance, astronauts may experience space motion sickness, gastrointestinal discomfort, a dulled sense of taste, and busy schedules (Clément, 2011). It is not clear if astronauts under these conditions would exhibit the same food preferences, such as the preference for an entrée, a side, and a dessert. However, there is no perfect way to simulate spaceflight on Earth. Bed rest and closed habitats (e.g., NASA's isolated HERA habitat) are common ways to attempt simulation, but although bed rest can simulate some of the effects of microgravity, it cannot simulate the social situations. And although closed habitats can simulate the social situations, they cannot simulate microgravity. In the study described here, I attempted to conduct an analog-type study by using a sample of commercial aerospace employees with high workloads. Although this sample and the environment were not perfect analogs for flights in the Crew Transportation Vehicle, they were the most representative sample that could be obtained for this study.

A final limitation of this study is that it did not include a measure of body composition that could separately assess fat mass, lean mass, and water mass. Given that astronauts tend to lose weight during spaceflight, and that the participants in this study lost weight, it is important to get a better measure of how body mass changes during the course of eating commercial space food. Future studies of commercial space food diets should assess weight change using DXA scans or other measures that accurately assess body composition.

**Implications and Future Directions**

This study was the first to evaluate a possible commercial space food diet made entirely of commercial, ready-to-eat food. Findings from this study showed that the diet, when eaten by commercial aerospace employees, did not lead to significant changes in caloric intake, mood, self-rated health, perceived stress, perceived social disconnection, or sleep. However, when eating the ready-to-eat food, participants did lose weight, possibly due to consuming less water. The commercial, ready-to-eat diet was also rated by participants as being slightly less hedonically rewarding and participants reported being slightly less satisfied with the variety of the food. However, as hypothesized, the commercial, ready-to-eat food was rated within two points of the control food on the 9-point Hedonic Scale, as well as on the scale assessing satisfaction with variety. It should also be noted that half of the commercial, ready-to-eat food items were rated 6.0 (“like slightly”) or better, which is NASA’s cut-off for acceptability.

When eating the commercial, ready-to-eat food, participants desired fewer sweets and, in post-study qualitative interviews, expressed the desire for more meats, fruits, vegetables, and real desserts, so as to provide the sensation of receiving a "real" meal with an entrée, a side, and a dessert. Participants also provided suggestions for how the diet could be improved. These suggestions should be incorporated prior to flying the diet in the Crew Transportation Vehicle. Research comparing a standard diet, such as the one used in this study, to personalized diets chosen by crewmembers should also be conducted, as allowing crewmembers to choose their own food may further increase food satisfaction. Providing personalized diets may also reduce the likelihood of flying unnecessary mass in the form of uneaten food.

Although the aim of this study was to evaluate a diet for use by humans in outer space, the findings have implications for humans on Earth, as well. The consumption of commercial, ready-to-eat food has become commonplace, if not the norm, for many individuals in developed nations. Ready-to-eat food makes up a majority (68.1%) of U.S. household consumer packaged goods purchases, with 61% of the calories purchased coming from highly processed food that is "no longer recognizable as their original plant/animal source" (analysis of 157,000 U.S. households; Poti, Mendez, Ng, & Popkin, 2015, Table 1). The consumption of ready-to-eat or ready-prepared meals is especially common among individuals of lower socioeconomic status due to work constraints and the perceived costliness of healthy food (Caraher, Dixon, Lang, & Carr-Hill, 1999; Inglis, Ball, Kylie, & Crawford, 2005).

The consequences of this increasing reliance upon ready-to-eat food is not yet clear. It is well known that consuming fresh fruits and vegetables is beneficial (Van Duyn & Pivonka, 2000) but what if these fruits and vegetables have been formed into ready-to-eat products? For instance, many of the foods included in the experimental diet contained dried fruit, nuts, flax seeds, and organic rolled oats. Are these ready-to-eat products healthy because they contain wholesome foods, or unhealthy, because they are processed to the point where the food sources are no longer recognizable? Processed and ready-to-eat foods have come under increasing scrutiny as a possible cause of obesity and chronic disease. Yet the usual criticism is that highly processed foods contain more fat, sugar, and salt than less processed foods (Monteiro, 2009; Moubarac et al., 2014). The experimental diet used in this study was comprised of entirely processed foods yet still met the Institute of Medicine's recommended macronutrient proportions. Is such a diet "healthy"? Or is it not possible to eat healthily while relying upon ready-to-eat food?

Because the study described here did not include direct measures of physiological health, it is not possible to conclude what sort of health consequences the diet may have had on a physiological level. Additionally, because participants ate the food for only four days, the findings cannot shed light on the possible health consequences of eating a ready-to-eat diet for months or years. However, this study did find that even short-term reliance upon ready-to-eat food may result in decreased food satisfaction. Given the large number of individuals who rely upon ready-to-eat food, and that reliance upon these foods is especially pronounced among individuals of lower socioeconomic status – who are disproportionately affected by many types of disease (Adler & Ostrove, 1999) – it seems advisable to further investigate the long-term consequences of eating ready-to-eat foods that are marketed as being healthy choices.

The findings from this study and future studies may also shed light on the health consequences of diets eaten by soldiers, arctic explorers, and others who rely upon ready-to-eat food. If the short-term diet investigated here is further improved and researched, it could potentially be used by these and other populations, especially in short-term emergency situations. For instance, given that the diet was low mass, ready-to-eat, and commercially available, it could potentially be used to provide short-term food relief to individuals in disaster situations.

## Conclusion

Overall, the findings of this study indicate that if the four-day diet of commercial, ready-to-eat food were provided to astronauts in the Crew Transportation Vehicle, the food itself would not lead to decreased caloric intake or to any obvious detriments in psychological or physical health. However, the diet, as designed, would likely be less hedonically rewarding to astronauts than freshly prepared food. Simple changes to the diet could increase astronauts' satisfaction with the food, such as providing more meal-like structures and adding more substantial proteins, fresh or dehydrated fruits and vegetables, and desserts. Allowing astronauts to personalize their diets may also increase food satisfaction and reduce the likelihood of flying unnecessary mass in the form of uneaten food. Further research is required to determine if these changes would be effective; the real test will be when the food is flown in outer space. Knowledge gained from this study, as well as the studies to come, will enable us to promote the physical and psychological health of humans: on Earth, in the Crew Transportation Vehicle, and beyond.

# Appendices

## Appendix A - Work-Specific Food Survey

Question 1. For the purposes of this study, are you willing and able to eat:

- Nuts
- Beef and pork
- Chicken and turkey
- Milk
- Egg
- Soy
- Gluten
- Sesame
- Processed foods
- Sugar and other carbohydrates
- White bread
- Room-temperature food for 4 days straight, including room-temperature beef jerky and noodles

Response Options:

- Yes
- Maybe
- No

Question 2. Are all of the following statements true of you?

- I would like to travel to outer space in the future
- I am willing and able to eat breakfast, lunch, and dinner at work, Monday through Thursday, for two consecutive weeks
- I am willing and able to eat ONLY the food provided to me during the 4 days of the Experimental Condition (essentially room-temperature "camping food" that contains meat and dairy items)
- I am willing and able to eat ONLY food served at work during the 4 days of the Control Condition
- I have no endocrine or metabolic disorder
- I am not currently dieting or trying to lose weight
- I have no history of an eating disorder

Response Options:

- Yes, all of the statements above are true of me
- No, at least one of the statements above is not true of me

Question 3. Would people call you a "picky" or "fussy" eater?

Response Options:

- Yes
- Maybe
- No

Question 4. Do you completely avoid refined carbohydrates, beef, pork, or dairy?

Response Options:

- Yes

- Maybe
- No

Question 5. How often do you eat breakfast that is SERVED AT work?

Response Options:

- Never
- Once or twice a week
- Three or four times a week
- Five or more times a week

Question 6. How often do you eat lunch that is SERVED AT work?

Response Options:

- Never
- Once or twice a week
- Three or four times a week
- Five or more times a week

Question 7. How often do you eat dinner that is SERVED AT work?

Response Options:

- Never
- Once or twice a week
- Three or four times a week
- Five or more times a week

Question 8. When you do not eat food that is served at work for breakfast, why not?

Response Options:

- I don’t eat this meal

- I eat this meal before/after work
- I bring food from home for this meal
- I go out to eat for this meal
- Other

Question 9. When you do not eat food that is served at work for lunch, why not?

Response Options:

- I don’t eat this meal
- I eat this meal before/after work
- I bring food from home for this meal
- I go out to eat for this meal
- Other

Question 10. When you do not eat food that is served at work for dinner, why not?

Response Options:

- I don’t eat this meal
- I eat this meal before/after work
- I bring food from home for this meal
- I go out to eat for this meal
- Other

Question 11. Where do you normally eat your meals? (check all that apply)

- At home
- At my desk
- Cafeteria / Mezz
- Outside, at work

- At a restaurant
- Other

Question 12. Are there any foods you eat most every day, such as Soylent, Juice, meal replacement bars?

## Appendix B - Condition Instructions

### Experimental Condition Instructions

This Monday, Tuesday, Wednesday, and Thursday, you are to eat breakfast, lunch, and dinner at work. You will only eat the food from this tote bag, and no other food. You may eat snacks at home or out-and-about after work, but these snacks must come from the food provided here.

This tote bag contains 4 bags of food labeled Day 1, Day 2, Day 3, and Day 4. Bring this tote bag with you anywhere you may want to eat (e.g., to home and back to work). You may pick and choose what to eat from any of the four bags, at any time of the day. However, you are encouraged to eat from only one bag per day, so that you will have sufficient food to eat on all four days.

Eat only what you want from the food provided. You do not need to eat all the food.

You *are,* however, strongly encouraged to try every type of food in your tote bag. The foods in your tote have been taste tested by SpaceX employees and were rated as very tasty. I expect that you will find the food, even the food that may be unfamiliar to you (such as the sandwiches) to be very tasty.

Eat your meals and snacks at the time you would normally eat, in the places where you would normally eat, and with the people with whom you would normally eat. For example, if you normally eat lunch at 12:00pm with your colleagues on the Mezz, keep doing that. However, do not let anyone else eat any of your food, as that would throw off my measurements! If someone asks to have a bite of your food, tell them “no,” as your food intake is being assessed as part of this study. If they really want to try the food (as I assure you, it is tasty), you can refer them to me and I will give them a sample.

For the next four days, after you eat or drink ANYTHING, write that what that food or drink is on the Food Rating Log for that day (the Food Rating Logs are behind this sheet). Please take a look at the Food Rating Log now, and then come back to this instruction sheet.

On the Food Rating Log, for Amount, you can write down "1" if you eat the whole package of food, "1/2" if you only ate half of it, or "1 bite" if you took one bite and didn't finish the rest. Rate each item that you eat (even if you only ate part of it) using the 1 ("dislike extremely") to 9 ("like extremely") scale that is shown on the Food Rating Log.

You can drink water, tea, and black coffee (no soda, and no cream or sugar in any drinks), but be sure to write down every time you drink and how much you drank (e.g., 12oz coffee, 20oz water) on the Food Rating Log, as you would write down food. You do NOT need to rate your drinks using the 1 to 9 scale.

This tote bag also contains four empty gallon-sized bags, labeled Monday, Tuesday, Wednesday, and Thursday Trash. Each time you eat something, put all your leftovers – both leftover food and packaging – in the bag for that day.

Tuesday, Wednesday, Thursday, and Friday morning between 8:00am and 10:00am, bring your previous day's Food Rating Log and your previous day's bag of leftovers to me in the Kitchen Office. On Friday morning, you will also hand over all remaining food. If you run out of food before Friday, just let me know and I will provide you with more food.

You will be weighed today and Friday morning, before you eat breakfast, in the Kitchen Office. Monday, Tuesday, Wednesday, and Thursday at 5:00pm, you will receive a link to an online survey via email. You will receive a text message to remind you to complete the survey at 6:00pm and at 7:00pm each night. You are expected to complete the survey before 8:00pm. Please complete this survey on a computer, as it may not work on your phone.

Control Condition Instructions

This Monday, Tuesday, Wednesday, and Thursday, you are to eat breakfast, lunch, and dinner at work. You can eat whatever you want for these meals from the Mezz, the Grill, the Dragon Wagon, and the Sandwich Line. You may also eat the yogurt parfaits and the milk/cereal from the Grab-and-Go area, but not the other foods (not the sandwiches/wraps, variety boxes, or juice). Do NOT order or eat anything from the frozen yogurt stand, the coffee bar (except for plain coffee/tea with no sugar/creamer added), the smoothie line, or the salad bar.

Eat your meals and snacks at the time you would normally eat, in the places where you would normally eat, and with the people with whom you would normally eat. For example, if you normally eat lunch at 12:00pm with your colleagues on the Mezz, keep doing that. However, do not let anyone else eat any of your food, as that would throw off my measurements! If someone asks to have a bite of your food, tell them "no," as your food intake is being assessed as part of this study.

For the next four days, after you eat or drink ANYTHING, write that what that food or drink is on the Food Rating Log for that day (the Food Rating Logs are behind this sheet). Please take a look at the Food Rating Log now, and then come back to this instruction sheet.

On the Food Rating Log, write down ALL the food and drink ITEMS that you consume, such as "Turkey sandwich," "Green salad with dressing," "French fries," etc. Be sure to include your sides! If you selected cereal/milk from the Grab-and-Go area, be sure to write down what type of cereal and what type of milk, and whether you had all the milk, or just some of it.

On the Food Rating Log, for Amount, you can write down “1” if you eat the whole plate of food, “1/2” if you only ate half of it, or “1 bite” if you took one bite and didn’t finish the rest. Rate each item that you eat (even if you only ate part of it) using the 1 (“dislike extremely”) to 9 (“like extremely”) scale that is shown on the Food Rating Log.

You can eat snacks at home, but be sure to write them on your Food Rating Log, as well as the quantity that you ate. Please be as specific as possible with these items (e.g., Nature Valley Cinnamon Granola Bar, one package) so that I can estimate what you ate.

You can drink water, tea, and black coffee (no soda, and no cream or sugar in any drinks), but be sure to write down every time you drink and how much you drank (e.g., 12oz coffee, 20oz water) on the Food Rating Log, as you would write down food. You do NOT need to rate your drinks using the 1 to 9 scale.

Tuesday, Wednesday, Thursday, and Friday morning, meet me in the Kitchen Office between 8:00am and 10:00am to turn your previous day’s Food Rating Log.

You will be weighed today and Friday morning, before you eat breakfast, in the Kitchen Office. Monday, Tuesday, Wednesday, and Thursday at 5:00pm, you will receive a link to an online survey via email. You will receive a text message to remind you to complete the survey at 6:00pm and at 7:00pm each night. You are expected to complete the survey before 8:00pm. Please complete this survey on a computer, as it may not work on your phone.

Appendix C - Food Rating Log

| Dislike Extremely | Dislike Very Much | Dislike Moderately | Dislike Slightly | Neither Like Nor Dislike | Like Slightly | Like Moderately | Like Very Much | Like Extremely |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

| Time | Location | Name of Food | Amount | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

Appendix D - Ten-Item Personality Inventory

Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

1 = Disagree strongly

2 = Disagree moderately

3 = Disagree a little

4 = Neither agree nor disagree

5 = Agree a little

6 = Agree moderately

7 = Agree strongly

1. _____ Extraverted, enthusiastic
2. _____ Critical, quarrelsome
3. _____ Dependable, self-disciplined
4. _____ Anxious, easily upset
5. _____ Open to new experiences, complex
6. _____ Reserved, quiet
7. _____ Sympathetic, warm
8. _____ Disorganized, careless
9. _____ Calm, emotionally stable
10. _____ Conventional, uncreative

Appendix E - Food Monotony Scale

| | Extremely Dissatisfied | | | | | | | | Extremely Satisfied |
|---|---|---|---|---|---|---|---|---|---|
| In general, how satisfied are you with the food you ate today? | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

| | Not at all | | | | | | | | Extremely |
|---|---|---|---|---|---|---|---|---|---|
| How much do you think you will want to eat the same foods (that you ate today) tomorrow? | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

Appendix F - Appetite Scale

Select the responses that best describe your appetite. Provide your scores based on your appetite at the moment, without concern for calories, fat, or a healthy diet.

How hungry do you feel right now?

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

How much would you like to eat something sweet? (cake, candy, cookies, ice cream, & pastry)

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

How much would you like to eat something salty? (chips, salted nuts, pickles, and olives)

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

How much would you like to eat something starchy? (bread, pasta, cereal, and potatoes)

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

How much would you like to eat fruit or fruit juices?

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

How much would you like to eat vegetables?

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

How much would you like to eat meat, poultry, fish, and eggs?

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

How much would you like to eat diary? (milk, cheese, & yogurt)

Not at all |______|______|______|______|______|______|______|______|______|______| Very much

Appendix G - Brunel Mood Scale 24

Below is a list of words that describe feelings. Please read each one carefully. Then mark the box that best describes HOW YOU FEEL RIGHT NOW. Make sure you answer every question.

| | Not at all | A little | Moderately | Quite a bit | Extremely |
|---|---|---|---|---|---|
| Panicky | 1 | 2 | 3 | 4 | 5 |
| Lively | 1 | 2 | 3 | 4 | 5 |
| Confused | 1 | 2 | 3 | 4 | 5 |
| Worn out | 1 | 2 | 3 | 4 | 5 |
| Depressed | 1 | 2 | 3 | 4 | 5 |
| Downhearted | 1 | 2 | 3 | 4 | 5 |
| Annoyed | 1 | 2 | 3 | 4 | 5 |
| Exhausted | 1 | 2 | 3 | 4 | 5 |
| Mixed-up | 1 | 2 | 3 | 4 | 5 |
| Sleepy | 1 | 2 | 3 | 4 | 5 |
| Bitter | 1 | 2 | 3 | 4 | 5 |
| Unhappy | 1 | 2 | 3 | 4 | 5 |
| Anxious | 1 | 2 | 3 | 4 | 5 |
| Worried | 1 | 2 | 3 | 4 | 5 |
| Energetic | 1 | 2 | 3 | 4 | 5 |
| Miserable | 1 | 2 | 3 | 4 | 5 |
| Muddled | 1 | 2 | 3 | 4 | 5 |
| Nervous | 1 | 2 | 3 | 4 | 5 |
| Angry | 1 | 2 | 3 | 4 | 5 |
| Active | 1 | 2 | 3 | 4 | 5 |
| Tired | 1 | 2 | 3 | 4 | 5 |
| Bad tempered | 1 | 2 | 3 | 4 | 5 |
| Alert | 1 | 2 | 3 | 4 | 5 |
| Uncertain | 1 | 2 | 3 | 4 | 5 |

Appendix H - Feelings of Social Disconnectedness Scale

Please indicate your agreement with the following statements.

| | Not at all | | | | Very much so |
|---|---|---|---|---|---|
| I feel like being around other people | 1 | 2 | 3 | 4 | 5 |
| I feel like being alone | 1 | 2 | 3 | 4 | 5 |
| I feel overly sensitive around others (e.g., my feelings are easily hurt) | 1 | 2 | 3 | 4 | 5 |
| I feel connected to others | 1 | 2 | 3 | 4 | 5 |
| I feel disconnected from others | 1 | 2 | 3 | 4 | 5 |

Appendix I - Perceived Stress Scale - 4

Over the past 24 hours, how often have you…

| | Never | Almost Never | Some-times | Fairly Often | Very Often |
|---|---|---|---|---|---|
| Felt that you were unable to control the important things in your life | 1 | 2 | 3 | 4 | 5 |
| Felt confident about your ability to handle your personal problems | 1 | 2 | 3 | 4 | 5 |
| Felt that things were going your way | 1 | 2 | 3 | 4 | 5 |
| Felt that difficulties were piling up so high that you could not overcome them | 1 | 2 | 3 | 4 | 5 |

Appendix J - General Self-Reported Health Item

In general, how would you rate your health today?

| Excellent | Very Good | Good | Fair | Poor |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Appendix K - Pittsburgh Sleep Quality Index

(Adapted for Past Four Days.) The following questions relate to your usual sleep habits during the past four days only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past four days, when have you usually gone to bed at night?
2. During the past four days, how long (in minutes) has it usually taken you to fall asleep each night?
3. During the past four days, when have you usually gotten up in the morning?
4. During the past four days, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spend in bed.)

For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past four days, how often have you had trouble sleeping because you…

| | Not during the past 4 days | Less than once | Once or twice | Three or more times |
|---|---|---|---|---|
| (a) …cannot get to sleep within 30 minutes | | | | |
| (b) …wake up in the middle of the night or early morning | | | | |
| (c) …have to get up to use the bathroom | | | | |
| (d) …cannot breathe comfortably | | | | |
| (e) …cough or snore loudly | | | | |

| | | | | |
|---|---|---|---|---|
| (f) …feel too cold | | | | |
| (g) …feel too hot | | | | |
| (h) …had bad dreams | | | | |
| (i) …have pain | | | | |
| (j) Other reason(s), please describe: | | | | |
| How often during the past four days have you had trouble sleeping because of this? | | | | |
| 6. During the past four days, how would you rate your sleep quality overall? | Very good | Fairly good | Fairly bad | Very bad |
| 7. During the past four days, how often have you taken medicine (prescribed or "over the counter") to help you sleep? | Not during the past four days | Less than once | Once or twice | Three or more times |
| 8. During the past four days, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity? | Not during the past four days | Less than once | Once or twice | Three or more times |
| 9. During the past four days, how much of a problem has it been for you to keep up enough enthusiasm to get things done? | No problem at all | Only a very slight problem | Somewhat of a problem | A very big problem |

## Appendix L - Post-Study Qualitative Questions

1. Which foods did you like the most?
2. Which foods did you dislike the most?
3. What foods would you like to eat again?
4. Has your experience in this study changed your thoughts about or understanding of space food?
5. How was the diet compared to how you thought it would be?
6. If the food in the study was more varied, but the food still had to be eaten cold, do you think your experience in the study would have been different? If so, how?
7. If you had been able to heat the food, how would your experience have been different?
8. What food would you like to see diet?
9. If you had this food in Crew Dragon [SpaceX's Crew Transportation Vehicle] for four days, how would you feel about it?
10. Were there any foods you didn't taste at all? If so, why didn't you try these foods?
11. Which foods would you like to eat again?
12. If you were having a really bad day, which of these foods would you want to eat?

## References

Adler, N. E., & Ostrove, J. M. (1999). Socioeconomic status and health: What we know and what we don't. *Annals of the New York Academy of Sciences*, *896*(1), 3-15. doi: 10.1111/j.1749-6632.1999.tb08101.x

Alkerwi, A. A., Crichton, G. E., & Hébert, J. R. (2015). Consumption of ready-made meals and increased risk of obesity: Findings from the Observation of Cardiovascular Risk Factors in Luxembourg (ORISCAV-LUX) study. *British Journal of Nutrition*, *113*(02), 270-277. doi: 10.1017/S0007114514003468

Altman, P. L., & Fisher, K. D. (1986). Research Opportunities in Nutrition and Metabolism in Space. NASA-CR-190992. Prepared for the Life Sciences Division, NASA. Retrieved from http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19930074290.pdf

Altman, P. L., & Talbot, J. M. (1987). Nutrition and metabolism in spaceflight. *The Journal of Nutrition*, *117*(3), 421-427. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/3572555

Backhaus, J., Junghanns, K., Broocks, A., Riemann, D., & Hohagen, F. (2002). Test–retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. *Journal of Psychosomatic Research*, *53*(3), 737-740. doi: 10.1016/S0022-3999(02)00330-6

Barger, L. K., Flynn-Evans, E. E., Kubey, A., Walsh, L., Ronda, J. M., Wang, W., ... & Czeisler, C. A. (2014). Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: An observational study. *The Lancet Neurology*, *13*(9), 904-912. doi: 10.1016/S1474-4422(14)70122-X

Bennett, J. W., Pascal H. H. M. Van Lieshout, Pelletier, C. A., & Steele, C. M. (2008). Sip-sizing behaviors in natural drinking conditions compared to instructed experimental conditions. *Dysphagia, 24*(2), 152-158. doi: 10.1007/s00455-008-9183-y

Biolo, G., Ciocchi, B., Stulle, M., Bosutti, A., Barazzoni, R., Zanetti, M., . . . & Guarnieri, G. (2007). Calorie restriction accelerates the catabolism of lean body mass during 2 wk of bed rest. *The American Journal of Clinical Nutrition*, *86*(2), 366-372. Retrieved from http://ajcn.nutrition.org/content/86/2/366.full.pdf

Bourland, C. T. (1993). The development of food systems for space. *Trends in Food Science & Technology*, *4*(9), 271-276. Retrieved from http://www.sciencedirect.com/science/article/pii/092422449390069M

Bowling, A. (2005). Just one question: If one question works, why ask several? *Journal of Epidemiology and Community Health*, *59*(5), 342-345. doi: 10.1136/jech.2004.021204

Bustead, R. L. & Tuony, J. M. (1966). Food quality design for Gemini and Apollo space programs. R67-6 Technical Library US Army Natick Laboratories Natick Mass. Retrieved from http://nsrdec.natick.army.mil/LIBRARY/59-69/R67-06.pdf

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193-213. Retrieved from http://xa.yimg.com/kq/groups/20795556/421574977/name/psqi+article.pdf

Caraher, M., Dixon, P., Lang, T., & Carr-Hill, R. (1999). The state of cooking in England: The relationship of cooking skills to food choice. *British Food Journal*, *101*(8), 590-609. doi: 10.1108/00070709910288289

Carpenter, J. S., & Andrykowski, M. A. (1998). Psychometric evaluation of the Pittsburgh Sleep Quality Index. *Journal of Psychosomatic Research*, *45*(1), 5-13. doi: 10.1016/S0022-3999(97)00298-5

Clément, G. (2011). *Fundamentals of space medicine* (2nd ed.). Space Technology Library (Vol. 23). New York, NY: Springer.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 385-396. Retrieved from http://www.jstor.org/stable/2136404

Collins, D. L. (1985). Psychological issues relevant to astronaut selection for long-duration space flight: A review of the literature. No. AFHRL-TP-84-41. *Air Force Human Resources Lab Brooks AFB TX*. Retrieved from http://www.dtic.mil/dtic/tr/fulltext/u2/a154051.pdf

De Graaf, C., De Jong, L. S., & Lambers, A. C. (1999). Palatability affects satiation but not satiety. *Physiology & Behavior*, *66*(4), 681-688. doi: 10.1016/S0031-9384(98)00335-7

De Souza, R. J., Bray, G. A., Carey, V. J., Hall, K. D., LeBoff, M. S., Loria, C. M., . . . & Smith, S. R. (2012). Effects of 4 weight-loss diets differing in fat, protein, and carbohydrate on fat mass, lean mass, visceral adipose tissue, and hepatic fat: Results from the POUNDS LOST trial. *The American Journal of Clinical Nutrition*, *95*(3), 614-625. doi: 10.3945/ajcn.111.026328

DeLongis, A., Coyne, J. C., Dakof, G., Folkman, S., & Lazarus, R. S. (1982). Relationship of daily hassles, uplifts, and major life events to health status. *Health Psychology*, *1*(2), 119. doi: 10.1037/0278-6133.1.2.119

DeNeui, D. (n.d.) Excel score TIPPI [table]. Ten item personality measure (TIPI). Retrieved from http://gosling.psy.utexas.edu/scales-weve-developed/ten-item-personality-measure-tipi/

Douglas, G. (2014, February). *The Challenges of Developing a Food System for Space Exploration.* Presentation at the National Space Biomedical Research Institute Nutrition Workshop, Houston, TX.

Drewnowski, A. (1997). Taste preferences and food intake. *Annual Review of Nutrition*, *17*(1), 237-253. doi: 10.1146/annurev.nutr.17.1.237

Eisenberger, N. I., Inagaki, T. K., Mashal, N. M., & Irwin, M. R. (2010). Inflammation and social experience: An inflammatory challenge induces feelings of social disconnection in addition to depressed mood. *Brain, Behavior, and Immunity*, *24*(4), 558-563. doi: 10.1016/j.bbi.2009.12.009

Fitts, R. H., Riley, D. R., & Widrick, J. J. (2000). Physiology of a microgravity environment invited review: Microgravity and skeletal muscle. *Journal of Applied Physiology*, *89*(2), 823-839. Retrieved from http://jap.physiology.org/content/89/2/823.full

Gallagher, D., Kovera, A. J., Clay-Williams, G., Agin, D., Leone, P., Albu, J., . . . & Heymsfield, S. B. (2000). Weight loss in postmenopausal obesity: No adverse alterations in body composition and protein metabolism. *American Journal of Physiology - Endocrinology and Metabolism*, *279*(1), E124-E131. Retrieved from http://ajpendo.physiology.org/content/279/1/E124

Gold, M., Franks, P., & Erickson, P. (1996). Assessing the health of the nation. The predictive validity of a preference-based measure and self-rated health. *Medical Care*, *34*(2), 163-177. Retrieved from http://journals.lww.com/lwwmedicalcare/Abstract/1996/02000/Assessing_the_Health_of_the_Nation__The_Predictive.8.aspx

Gosling, S. D., Rentfrow, P. J., & Potter, J. (2014). Norms for the Ten Item Personality Inventory. Unpublished Data. Retrieved from http://gosling.psy.utexas.edu/scales-weve-developed/ten-item-personality-measure-tipi

Gosling, S. D., Rentfrow, P. J., & Swann, W. B., Jr. (2003). A very brief measure of the Big Five personality domains. *Journal of Research in Personality, 37,* 504-528. doi: 10.1016/S0092-6566(03)00046-1

Grandner, M. A., Jackson, N., Gerstner, J. R., & Knutson, K. L. (2013). Dietary nutrients associated with short and long sleep duration. Data from a nationally representative sample. *Appetite*, *64*, 71–80. doi: 10.1016/j.appet.2013.01.004

Heavens, K. R., Charkoudian, N., O'Brien, C., Kenefick, R. W., & Cheuvront, S. N. (2016). Noninvasive assessment of extracellular and intracellular dehydration in healthy humans using the resistance-reactance-score graph method. *The American Journal of Clinical Nutrition*, *103*(3), 724-729. doi: 10.3945/ajcn.115.115352

Hill, A. J., Magson, L. D., & Blundell, J. E. (1984). Hunger and palatability: Tracking ratings of subjective experience before, during and after the consumption of preferred and less preferred food. *Appetite*, *5*(4), 361-371. doi: 10.1016/S0195-6663(84)80008-2

Hollender, H. (1969). U.S. Army Food R&D Program. Session at NASA's Aerospace Food Technology conference, University of South Florida. Tampa, Florida. April 15-17 1969. Retrieved from http://history.nasa.gov/SP-202/sess5.5.htm

Idler, E. L., & Benyamini, Y. (1997). Self-rated health and mortality: A review of twenty-seven community studies. *Journal of Health and Social Behavior*, 21-37. Retrieved from http://www.jstor.org/stable/2955359

Idler, E. L., & Kasl, S. V. (1995). Self-ratings of health: Do they also predict change in functional ability? *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *50*(6), S344-S353. doi: 10.1093/geronb/50B.6.S34

Inglis, V., Ball, K., & Crawford, D. (2005). Why do women of low socioeconomic status have poorer dietary behaviours than women of higher socioeconomic status? A qualitative exploration. Appetite, 45(3), 334-343. Retrieved from http://dro.deakin.edu.au/eserv/DU:30003101/ball-whydowomenoflow-2005.pdf

Institute of Medicine (2005a). Dietary Reference Intakes for Energy, Carbohydrate. Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Retrieved from https://www.nationalacademies.org/hmd/~/media/Files/Activity%20Files/Nutrition/DRIs/DRI_Macronutrients.pdf

Institute of Medicine (2005b). Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. Retrieved from http://www.nationalacademies.org/hmd/~/media/Files/Activity%20Files/Nutrition/DRIs/DRI_Electrolytes_Water.pdf

Jamoom, E.W., Horner-Johnson, W., Suzuki, R., Andresen, E.M., Campbell, V.A., & RRTC Expert Panel on Health Status Measurement (2008). Age at disability onset and self-reported health status. *BMC Public Health, 8,* 1-7. doi: 10.1186/1471-2458-8-10

Jones, L.V., Peryam, D.R., & Thurstone, L. L. (1955). Development of a scale for measuring soldiers' food preferences. *Food Research, 20*, 512-520. doi: 10.1111/j.1365-2621.1955.tb16862.x

Kanas, N. (1987). Psychological and interpersonal issues in space. *American Journal of Psychiatry*, *144*(6), 703-709. doi: 10.1176/ajp.144.6.703

Kaplan, G. A., & Camacho, T. (1983). Perceived health and mortality: A nine-year follow-up of the human population laboratory cohort. *American Journal of Epidemiology*, *117*(3), 292-304. Retrieved from http://aje.oxfordjournals.org/content/117/3/292.short

Kerwin, J., & Seddon, R. (2002). Eating in space—from an astronaut's perspective. *Nutrition*, *18*(10), 921-925. doi: 10.1016/S0899-9007(02)00935-8

Keys, A. (1946). Human starvation and its consequences. *Journal of the American Dietetic Association*, *22*, 582-587. Retrieved from http://psycnet.apa.org/psycinfo/1948-02869-001

Keys, A., Brožek, J., Henschel, A., Mickelsen, O., & Taylor, H. L. (1950). The biology of human starvation. Minneapolis, MN: University of Minnesota Press.

Killgore, W. D.S. (2010). *Effects of sleep deprivation on cognition.* In Progress in Brain Research, vol. 185 (Eds. Kerkhof, G. A., & Van Dongen, H. P. A.). London, England: Elsevier.

King, S. C., Meiselman, H. L., Hottenstein, A. W., Work, T. M., & Cronk, V. (2007). The effects of contextual variables on food acceptability: A confirmatory study. *Food Quality and Preference*, *18*(1), 58-65. doi: 10.1016/j.foodqual.2005.07.014

Lane, H. W., & Feeback, D. L. (2002). Water and energy dietary requirements and endocrinology of human space flight. *Nutrition*, *18*(10), 820-828. doi: 10.1016/S0899-9007(02)00936-X

Lane, H. W., Gretebeck, R. J., Schoeller, D. A., Davis-Street, J., Socki, R. A., & Gibson, E. K. (1997). Comparison of ground-based and space flight energy expenditure and water turnover in middle-aged healthy male US astronauts. *American Journal of Clinical Nutrition*, *65*, 4-12. Retrieved from http://ajcn.nutrition.org/content/65/1/4.short

Lane, H. W., Kloeris, V., Perchonok, M. H., Zwart, S. R., & Smith, S. M. (2006). *Changes in Nutritional Issues over the Last 45 Years.* (Report 20060048511). Retrieved from NASA Technical Reports Server: https://ntrs.nasa.gov/search.jsp?R=20060048511

Lane, H. W., Smith, S. M., Rice, B. L., & Bourland, C. T. (1994). Nutrition in space: Lessons from the past applied to the future. *The American Journal of Clinical Nutrition*, *60*(5), 801S-805S. Retrieved from http://ajcn.nutrition.org/content/60/5/801S.short

Lombardi, D. A., Folkard, S., Willetts, J. L., & Smith, G. S. (2010). Daily sleep, weekly working hours, and risk of work-related injury: US National Health Interview Survey (2004–2008). *Chronobiology International*, *27*(5), 1013-1030. doi: 10.3109/07420528.2010.489466

Lund Research Ltd. (2013a). ANOVA with repeated measures using SPSS Statistics. Retrieved from https://statistics.laerd.com/spss-tutorials/one-way-anova-repeated-measures-using-spss-statistics.php

Lund Research Ltd. (2013b). Two-way repeated measures ANOVA using SPSS Statistics. Retrieved from https://statistics.laerd.com/spss-tutorials/two-way-repeated-measures-anova-using-spss-statistics.php

Mallis, M. M., & DeRoshia, C. W. (2005). Circadian rhythms, sleep, and performance in space. *Aviation, Space, and Environmental Medicine*, *76*(6), B94-B107. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15943202

Marshall, J. A., Scarbro, S., Shetterly, S. M., & Jones, R. H. (1998). Improving power with repeated measures: Diet and serum lipids. *The American Journal of Clinical Nutrition*, *67*(5), 934-939. Retrieved from http://ajcn.nutrition.org/content/67/5/934.short

Marx de Salcedo, A. (2015). *Combat ready kitchen.* New York City, NY: Current / Penguin Random House.

Matsumoto, A., Storch, K. J., Stolfi, A., Mohler, S. R., Frey, M. A., & Stein, T. P. (2011). Weight loss in humans in space. *Aviation, Space, and Environmental Medicine*, *82*(6), 615-621. doi: 10.3357/ASEM.2792.2011

McClements, J. (n.d.) Analysis of Ash and Minerals. Retrieved from http://people.umass.edu/~mcclemen/581Ash&Minerals.html

McNair, D. M., Lorr, M., & Droppelman, L. F. (1971). *Manual for the Profile of Mood States*. San Diego, CA: Educational and Industrial Testing Services.

Meiselman, H. L. (2006) Context in Food Choice, Acceptance and Consumption. In Shepherd, R. & Raats, M. (Eds.), *The Psychology of Food Choice* (179-200). Guildford, UK: Food, Consumer Behaviour and Health Research Centre, Department of Psychology, University of Surrey.

Meiselman, H. L., de Graaf, & Lesher, L. L. (2000). The effects of variety and monotony on food acceptance and intake at a midday meal. *Physiology & Behavior, 70*(1), 119-125. doi: 10.1016/S0031-9384(00)00268-7

Monteiro, C. A. (2009). Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public Health Nutrition*, *12*(05), 729-731. doi: 10.1017/S1368980009005291

Moubarac, J. C., Batal, M., Martins, A. P. B., Claro, R., Levy, R. B., Cannon, G., & Monteiro, C. (2014). Processed and ultra-processed food products: Consumption trends in Canada from 1938 to 2011. *Canadian Journal of Dietetic Practice and Research*, *75*(1), 15-21. doi: 10.3148/75.1.2014.15

Musson, D. M., Sandal, G. M., & Helmreich, R. L. (2004). Personality characteristics and trait clusters in final stage astronaut selection. *Aviation, Space, and Environmental Medicine*, *75*(4), 342 – 349. Retrieved from http://www.ingentaconnect.com/content/asma/asem/2004/00000075/00000004/art00007

National Aeronautics and Space Administration (2002). NASA Facts: Space Food. FS-2002-10-079-JSC. Retrieved from http://spaceflight.nasa.gov/spacenews/factsheets/pdfs/food.pdf

National Aeronautics and Space Administration (2008). Flammability, odor, offgassing, and compatibility requirements and test procedures for materials in environments that support combustion (NASA-STD-(I)-6001A). Retrieved from https://www.nasa.gov/centers/johnson/pdf/485934main_NASA-STD-(I)-6001A%20Released.pdf

NASA Astronaut Selection Program (n.d.). Frequently Asked Questions. Retrieved from http://astronauts.nasa.gov/content/faq.htm

Osdoba, K. E., Mann, T., Redden, J. P., & Vickers, Z. (2015). Using food to reduce stress: Effects of choosing meal components and preparing a meal. *Food Quality and Preference*, *39*, 241-250. doi: 10.1016/j.foodqual.2014.08.001

Perchonok, M., & Bourland, C. (2002). NASA food systems: past, present, and future. *Nutrition*, *18*(10), 913-920. doi: 10.1016/S0899-9007(02)00910-3

Peryam, D.R. & Girardot, N.F. (1952). Advanced taste test method. *Food Engineering, 24,* 58-61, 194. Retrieved from http://www.pk-research.com/services/media/paperandpublications/theninepointhedonicscale-papers.pdf

Pietrzyk, R. A., Jones, J. A., Sams, C. F., & Whitson, P. A. (2007). Renal stone formation among astronauts. *Aviation, Space, and Environmental Medicine*, *78*(Supplement 1), A9-A13. Retrieved from http://www.ingentaconnect.com/content/asma/asem/2007/00000078/A00104s1/art00004

Pilcher, J. J., & Huffcutt, A. J. (1996). Effects of sleep deprivation on performance: A meta-analysis. *Sleep*, *19*(4), 318-326. Retrieved from http://psycnet.apa.org/psycinfo/1997-07865-006

Poti, J. M., Mendez, M. A., Ng, S. W., & Popkin, B. M. (2015). Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *The American Journal of Clinical Nutrition*. doi: 10.3945/ajcn.114.100925

Redden, J. (2013). Food satisfaction and boredom measure. University of Minnesota, Twin Cities.

Ries, C. P., Kline, K., & Weaver, S. O. (1987). Impact of commercial eating on nutrient adequacy. *Journal of the American Dietetic Association*, *87*(4), 463-468. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/3559005

Schmider, E., Ziegler, M., Danay, E., Beyer, L., & Bühner, M. (2010). Is it really robust? *Methodology, 6,* 147-151. doi: 10.1027/1614-2241/a000016

Schwartz, B., Ward, A., Monterosso, J., Lyubomirsky, S., White, K., & Lehman, D. R. (2002). Maximizing versus satisficing: happiness is a matter of choice. *Journal of Personality and Social Psychology*, *83*(5), 1178-1197. doi: 10.1037//0022-3514.83.5.1178

Shields, M., & Shooshtari, S. (2001). Determinants of self-perceived health. *Health Reports*, *13*(1), 35. Retrieved from https://www.researchgate.net/profile/Shahin_Shooshtari/publication/8631507_Determinants_of_self-perceived_health/links/02e7e515c97cd118ba000000.pdf

Slack, K. J., Holland, A., & Sipes, W. (2014, August). Selecting astronauts: The role of psychologists. Presented at the American Psychological Association Conference, Washington, D.C.

Smith, S. M., & Zwart, S. R. (2008). Nutrition issues for space exploration. *Acta Astronautica*, *63*(5), 609-613. doi: 10.1016/j.actaastro.2008.04.010

Smith, S. M., Zwart, S. R., Block, G., Rice, B. L., Davis-Street, J. E. (2005). The nutritional status of astronauts is altered after long-term space flight aboard the International Space Station. *American Society for Nutritional Services*, 135(3), 437–443. Retrieved from http://jn.nutrition.org/content/135/3/437.full.pdf+html

Smith, S. M., Zwart, S. R., Kloeris, V. L., & Heer, M. A. (2009). *Nutritional biochemistry of space flight.* Hauppauge, NY: Nova Science Publishers, Inc.

Sørensen, L. B., Møller, P., Flint, A., Martens, M., & Raben, A. (2003). Effect of sensory perception of foods on appetite and food intake: A review of studies on humans. *International Journal of Obesity*, *27*(10), 1152-1166. doi: 10.1038/sj.ijo.0802391

Spiegel, K., Tasali, E., Penev, P., & Van Cauter, E. (2004). Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Annals of Internal Medicine*, *141*(11), 846-850. doi: 10.7326/0003-4819-141-11-200412070-00008

Stein, T. P., Leskiw, M. J., Schluter, M. D., Hoyt, R. W., Lane, H. W., Gretebeck, R. E., & LeBlanc, A. D. (1999). Energy expenditure and balance during spaceflight on the space shuttle. *American Journal of Physiology*, *276*(6), R1739-R1748. Retrieved from http://ajpregu.physiology.org/content/276/6/R1739

Stuster, J. (2010). Behavioral issues associated with long duration space expeditions: Review and analysis of astronaut journals. NASA/TM-2010-216130. Retrieved from http://ston.jsc.nasa.gov/collections/trs/_techrep/TM-2010-216130.pdf

Szinnai, G., Schachinger, H., Arnaud, M. J., Linder, L., & Keller, U. (2005). Effect of water deprivation on cognitive-motor performance in healthy men and women. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *289*(1), R275-R280. doi: 10.1152/ajpregu.00501.2004

Terry, P. C., Lane, A. M., & Fogarty, G. J. (2003). Construct validity of the POMS - Adolescents for use with adults. *Psychology of Sport and Exercise*, *4*, 125-139. doi: 10.1016/S1469-0292(01)00035-8

Terry, P. C., Lane, A. M., Lane, H. J., & Keohane, L. (1999). Development and validation of a mood measure for adolescents. *Journal of Sports Sciences*, *17*, 861-872. doi: 10.1080/026404199365425

Thornton, W. E., & Bonato, F. (2013). Space motion sickness and motion sickness: Symptoms and etiology. *Aviation, Space, and Environmental Medicine*, *84*(7), 716-721. Retrieved from http://www.ingentaconnect.com/content/asma/asem/2013/00000084/00000007/art00009

Tomiyama, A. J., Mann, T., Vinas, D., Hunger, J. M., DeJager, J., & Taylor, S. E. (2010). Low calorie dieting increases cortisol. *Psychosomatic Medicine, 72*(4), 357–364. doi: 10.1097/PSY.0b013e3181d9523c

Tracy, C. R., Best, S., Bagrodia, A., Poindexter, J. R., Adams-Huet, B., Sakhaee, K., . . . & Pearle, M. S. (2014). Animal protein and the risk of kidney stones: A comparative metabolic study of animal protein sources. *The Journal of Urology*, *192*(1), 137-141. doi: 10.1016/j.juro.2014.01.093

U.S. National Library of Medicine (2015). Zolpidem. Retrieved from https://www.nlm.nih.gov/medlineplus/druginfo/meds/a693025.html

Van Duyn, M. A. S., & Pivonka, E. (2000). Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: Selected literature. *Journal of the American Dietetic Association*, *100*(12), 1511-1521. doi: 10.1016/S0002-8223(00)00420-X

Weiss, Robert M. (1969, April 15-17). *Food Development and Experiences.* Paper presented at Aerospace Food Technology Conference, Tampa, FL. Retrieved from http://history.nasa.gov/SP-202/sess4.2.htm

Wellek, S., & Blettner, M. (2012). On the proper use of the crossover design in clinical trials: Part 18 of a series on evaluation of scientific publications. *Deutsches Ärzteblatt International*, *109*(15), 276. Retrieved from http://www.aerzteblatt.de/pdf/DI/109/15/m276.pdf

Whitehead, B. R., & Bergeman, C. S. (2013). Self-reported health bias: The role of daily affective valence and arousal. *Psychological Health*, *28*(7), 784–799. doi: 10.1080/08870446.2012.759224

Whitmire, A., Slack, K., Locke, J., Keeton, K., Patterson, H., Faulk, J., & Leveton, L. (2013). Sleep Quality Questionnaire short-duration flyers. *National Aeronautics and Space Administration*, Johnson Space Center, Houston, TX. Retrieved from http://ston.jsc.nasa.gov/collections/trs/_techrep/TP-2013-217378.pdf

World Health Organization (2007). Study on global ageing and adult health. *INDEPTH Short Summary Module – Set A.* Retrieved from http://www.who.int/healthinfo/systems/WHO-INDEPTH_SAGE_A.pdf

Wotring, V. E. (2015). Medication use by US crewmembers on the International Space Station. *The Federation of American Societies for Experimental Biology Journal*, *29*(11), 4417-4423. doi: 10.1096/fj.14-264838

Yeomans, M. R. (1996). Palatability and the micro-structure of feeding in humans: The Appetizer Effect. *Appetite*, *27*, 119–133. doi: 10.1006/appe.1996.0040

Zijlstra, N., Wijk, R. D., Mars, M., Stafleu, A., & Graaf, C. D. (2009). Effect of bite size and oral processing time of a semisolid food on satiation. *American Journal of Clinical Nutrition*, *90*(2), 269-275. doi: 10.3945/ajcn.2009.27694