

# Positive Psychological Outcomes of Spaceflight: An Empirical Study

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**Introduction:** Anecdotes from astronauts and cosmonauts suggest that spaceflight can be an enriching experience with enduring positive effects. These positive mental health effects may help protect flight crews from the psychological stress inherent in such high-risk missions. The goal of this study was to identify areas of personal growth likely to result from traveling in space and explore how they were patterned. **Methods:** We developed a Positive Effects of Being in Space (PEBS) Questionnaire, which included a section adapted from the Post-Traumatic Growth Inventory (PTGI) as well as original items addressing experiences unique to spaceflight. We sent the anonymous questionnaire to 175 astronauts and cosmonauts who had flown on at least 1 mission; completed surveys were returned by 39 individuals. **Results:** Every respondent had a positive reaction to being in space, the strongest of which related to the Earth's beauty and fragility. Respondents reported changes in both attitudes and behaviors. Respondents appeared to cluster into two groups based on the intensity of their reported changes. Response patterns did not vary by demographic group, number of missions flown, or total elapsed time in space. **Conclusions:** Overall, our findings support the idea that being in space is a meaningful experience that makes an enduring positive impression on astronauts and cosmonauts. An enhanced understanding of the salutogenic effects of space travel will contribute to the education, training, and support of future space crewmembers.

**Keywords:** salutogenesis, coping, personality, adaptation, countermeasures.

CURIOSITY HAS inspired human beings to explore not only our world, but also the cosmos. Like other pioneering explorers before them, astronauts and cosmonauts have endured great risks and hardships—and occasionally have lost their lives—to achieve their missions of discovery. The psychological risks may be severe and stem from prolonged isolation from family and friends, confinement in close quarters, and survival in a hostile environment. These issues pose a challenge to the perseverance of those chosen for long-duration missions. As reviewed by Kanas and Manzey (9), many studies have investigated the mental health risks posed by the stress inherent in long-duration missions, such as those on the Mir and International Space Stations, as well as the proposed missions to the Moon and Mars. The potential mental health benefits of space missions have more rarely been discussed and have not been systematically studied empirically, despite some recent work concerning other isolated, confined environments (i.e., polar stations) and published anecdotal accounts. In short, there is scant scientific literature addressing the salutogenic (i.e., health-promoting, growth-enhancing) effects of space travel.

In fact, the concept of salutogenesis is a relatively modern one, coined in the era of space exploration; the term refers to processes by which powerful experiences enhance or bring about well-being (1,4,22,25,27). Research in the field of post-traumatic growth suggests that some individuals gain strength and wisdom from successfully coping with personal crises (4,25). In other words, negative stressors can produce positive change. Moreover, it also has been shown that positive stressors can bring about positive change, especially when the positive stressor is deliberately sought out. Studies documenting the affirmative psychological reactions to working in extreme environments (polar stations, submarines, etc.) suggest that individuals who can adapt positively to the demands of an inhospitable environment can derive benefit from their experiences (17,18,22,23). Many individuals report having derived great satisfaction from the challenges posed by their stressful experiences (23). Traveling and working in space is widely acknowledged to be stressful—in both exhilarating and distressing ways (9,10,22). Training for space missions and surviving a trauma both allow individuals to confront mortality, scrutinize strengths and weaknesses, and gain new insights. Thus, it is likely that being in space can be a salutogenic life experience.

Explorers have much to gain when their missions are successful. These gains may involve specific benefits to society, such as technologic advances and expanded knowledge of Earth's environment. Other benefits are more personal and transcendent, such as experiencing inspiration and awe. These psychological benefits may help astronauts and cosmonauts cope with stress. Space travelers have demonstrated a remarkable capacity to endure and thrive—in short, to adapt—under the stressful circumstances of space missions, some of very long duration. Evidence from the field of positive psy-

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chology suggests that adaptive functioning results from a complex interaction of external (environmental) pressures and personal qualities (15,16). When external pressures are extreme (as in space or in life-threatening situations), the motivation for adaptation is strong and the need for such personal qualities as adaptive coping is high (20).

One personal quality that has been shown to be important for psychological well-being in a wide variety of stressful settings is coping style. Current theories categorize coping styles as being approach-oriented or avoidance-oriented (15). In isolated and confined settings, such as those involving long-duration space missions, some forms of approach coping (such as seeking social support) may not be as normative or adaptive as in ordinary environments (17,18). In these settings, a coping style that is meaning-based may be more useful (5). Therefore, it is important to learn more about spacefarers' experiences in space, in part to gain insight into their coping styles, so that people involved with future missions can be advised about how best to adapt to and benefit from their experiences. The ability to harness the benefits of salutogenic experiences may play an important role in allowing for good coping, but little is known about it in the setting of space.

A review of the literature reveals only a few relevant publications addressing crewmembers' positive mental health experiences in space. In a previous survey, a group of 54 astronauts and cosmonauts who had flown in space rated the excitement of spaceflight as one of the strongest factors enhancing communication among crewmembers (12) and between crewmembers and mission control support personnel on the Earth (13). This is important because good communications and working relationships are essential for crew safety and mission success, especially during long-duration space missions. Anecdotal information from astronauts and cosmonauts underscores that spaceflight is often an inspiring experience whose positive effects on attitudes, values, beliefs, and behaviors endure for some time after flight crews have returned to Earth (2,3,26).

Only one other scientific study aside from the current one has analyzed and quantified the long-term positive impact of spaceflight on mental health, and this was a content analysis of astronauts' memoirs (24). Using a thematic analysis of the values and emotions mentioned by four pioneering American astronauts, the investigators found that the relative importance of various values evolved over the course of these astronauts' careers, with some of these changes being attributable to their missions. For example, three of the four reported an increase in the value of Universalism [defined as "understanding, appreciation, tolerance, and protection for all people and for nature" (24, page C7)] during their mission, which further increased postflight. Furthermore, the authors also found that all four astronauts reported a relative increase in the value of Spirituality [defined as "meaning and inner harmony through transcendence" (24, page C7)] in the postflight phase of the missions. Further clarification and quantification of such experiences in a wider sample is important because such knowledge would inform the public

at large about the benefits of space travel; would contribute to the education, training, and care of future space crewmembers; and could be used to conduct more accurate risk-benefit analyses in the planning of future missions.

Our aim in the present study was to systematically confirm and quantify positive changes described in the literature by using a questionnaire specifically constructed to measure the positive impact of being in space on astronauts and cosmonauts who had flown on one or more space missions. We predicted that: 1) everyone would report some positive change; 2) change would occur in both attitudes and behaviors; 3) specific attitude changes would correspond to relevant behavioral changes (e.g., a greater appreciation of the beauty and fragility of the Earth would be correlated with a greater involvement in environmental causes, and a stronger understanding of the unity of humankind would be correlated with an increased involvement in politics and a stronger relationship with one's family), and that 4) the degree of change would be correlated with the amount of time spent in space. We also sought to explore whether the profile of positive changes varied across other types of respondent characteristics (e.g., number and type of missions, gender, nationality). Some of the findings were presented earlier at conferences using a partial dataset (7) and a subset of results [dictated by presentation constraints (19)]. This paper reports the final and complete results of our survey using our complete dataset.

## METHODS

### *Participants and Procedure*

Our anonymous sample was recruited from two sources: the Association of Space Explorers (ASE) and the current NASA astronaut corps. Membership in the ASE is limited to astronauts and cosmonauts of any nationality who have flown in space at least once, and ASE participation in our study was limited to members on the Association's e-mail distribution list (approximately 90 individuals). The sampling frame for the NASA astronauts consisted of 85 individuals who had flown in space and still had a mailbox at the Johnson Space Center (JSC). Some people may have been contacted more than once, possibly through both organizations or through word of mouth about the study. We are unable to determine if this is the case because, by agreement with both groups, our study team was not provided with a list of potential participants from either the ASE or JSC to maintain respondents' anonymity.

Human subjects approval was obtained from the University of California/San Francisco and the San Francisco Department of Veterans Affairs Medical Center Committee on Human Research, and the NASA-JSC Committee for the Protection of Human Subjects. Additionally, the request to involve active astronauts in the study was approved by the Astronaut Office. Our study questionnaire included a cover page informing participants of the study's purpose, risks, benefits, and anonymity protection procedures. Questionnaires were e-mailed to ASE members by their Executive Secretary

and returned to us electronically through an e-mail account constructed so that the sender could not be identified. Questionnaires were distributed to JSC astronauts as hard copies, which they returned to us anonymously via post or fax.

The final sample consisted of 39 respondents, including 10 from ASE and 29 from JSC (overall response rate of about 22% of the estimated 175 individuals who were contacted). In order to determine whether it was more parsimonious to consider the respondents as belonging to one large group or two smaller groups (ASE and JSC), we tested for differences between these two subgroups. Respondents from the ASE and JSC had similar means on our measure for the total score and all eight subscale scores (*t*-tests all non-significant). Furthermore, stratifying analyses by source made no difference in the pattern of results. Thus, in the absence of evidence for differences based on source, we report results below for the entire set of 39 respondents as a group. Each individual's demographic profile was different enough from the others so that it was unlikely that one person completed more than one questionnaire. However, several respondents did not fully complete the demographics section of the questionnaire. Most respondents were American (34 of 37 completing this item), male (32 of 37), and had been on more than one mission (24 of 36), but spent less than 30 total days in space (20 of 36).

#### Instrument

Participants completed the Positive Effects of Being in Space (PEBS) Questionnaire, which is a 36-item questionnaire we developed to assess areas of personal growth that are likely to be positively influenced by travel in space. A sample questionnaire can be viewed online (Appendix A)\*. The PEBS is based on the Post-Traumatic Growth Inventory (PTGI) developed by Tedeschi and Calhoun (25). The PTGI has been shown to be valid and reliable as a measure of the positive personal growth that can occur following stressful events (4). We believed that this instrument would have relevance to our study participants because missions in space are inherently stressful. We used all 21 PTGI items and their resultant five subscales in our questionnaire (Table I). With the permission of Dr. Tedeschi (personal communication, October 2002), we also made several modifications which are described below.

We generated additional items more specific to space travel from themes found in the existing literature; these themes included teamwork, self-actualization, esthetic reactions to Earth and space observations, and spirituality (8,11,26). The resulting 15 items relating to experiences from space [which we termed the 'Positive Change from Space Travel' (PCST) items] were concatenated with the items of the PTGI. Based on content, 13 of these items were divided into 3 subscales (Table I) (2 items were omitted because of their low item-total correlations).

\* Appendix A can be found online at <http://www.ingentaconnect.com/content/asma/asm>.

We modified the instructions from the PTGI slightly to refer to the spaceflight experience rather than to a traumatic experience. All of the items (PCST and PTGI) were scored using a 6-point Likert-like scale adapted from the PTGI (ranging from 0 - "I did not experience this change" to 3 - "a moderate degree" to 5 - "a very great degree"). Because our questionnaire was designed to measure change, a score of "0" would not discriminate between a simple lack of change in the experience described in the item vs. a lack of room for change (i.e., the feelings were already as high as possible). To clarify this issue, we asked the respondents to indicate with a "starred" 0 (0\*) the items about which there was no prospect for change because their feelings were already at their maximum. Two open-ended free-response questions [question #37: "I experienced a positive change not addressed in the above items (. . . describe this change here)" and question #38: "Select the most powerful positive experience you had in space and describe it below"] were included near the end of the questionnaire to offer participants an opportunity to provide subjective comments about their experiences; the final question (#44) was also open-ended and queried the respondents about any comments they would like to add. A section ascertaining demographic data concluded the questionnaire (questions #39 to #43). To decrease the likelihood of respondent identification, the demographic data we sought was kept to a minimum. For example, a question regarding time elapsed since last mission was considered but ultimately excluded from the final questionnaire. The demographics questions were limited to the following categories: total number of days in space; number of missions flown (subdivided into those lasting less than 1 mo and those lasting 1 mo or more); nationality; and gender.

#### Statistical Analyses

All analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 12 (21). The criterion used for statistical significance was  $p < 0.05$  in two-tailed tests.

#### Psychometrics

We previously presented the psychometrics of the PEBS based on our preliminary dataset (7). For the sake of thoroughness, we ran the same psychometric analyses again with the complete dataset from 39 respondents. Confirming our previous findings, we found high internal consistency reliability ( $\alpha = 0.96$  for the entire PEBS,  $\alpha = 0.95$  for the PTGI items, and  $\alpha = 0.90$  for the PCST items). As shown by the high  $\alpha$  scores in Table I, the five subscales of the PTGI each had good internal consistency and reliability even though our sample population (astronauts and cosmonauts) was quite different from Tedeschi and Calhoun's original sample of trauma survivors (25). Also, the correlations between these five subscales ranged from 0.56 to 0.75, suggesting that they are related, but different, constructs.

For the space-specific PCST, the three subscales also had good internal consistency and reliability (Table I).

TABLE I. POSITIVE EFFECTS OF BEING IN SPACE QUESTIONNAIRE SUBSCALES AND ITEM-LEVEL STATISTICS.

Subscale (and items)	Alpha	Subscale (Mean $\pm$ SD)	Item (Mean $\pm$ SD)	% of n = 39 reporting any change
Perceptions of Earth (PCST)	0.84	2.94 $\pm$ 1.27		
I gained a stronger appreciation of the Earth's beauty.			4.18 $\pm$ 1.05	97.4
I learned to appreciate the fragility of the Earth.			3.13 $\pm$ 1.87	84.6
I realized how much I treasure the Earth.			2.92 $\pm$ 1.61	89.7
I increased my involvement in environmental causes.			1.54 $\pm$ 1.59	64.1
Perceptions of Space (PCST)	0.84	1.97 $\pm$ 1.43		
I gained a stronger sense of wonder about the universe.			2.67 $\pm$ 1.71	82.1
I became more excited about space exploration.			2.36 $\pm$ 1.89	69.2
I gained a new appreciation for the boundlessness of the Cosmos.			2.03 $\pm$ 1.95	61.5
I became interested in the possibility of life on other planets.			0.85 $\pm$ 1.39	38.5
Changes in Daily Life (PCST)	0.71	1.34 $\pm$ 1.01		
My relationship with my family grew stronger.			2.10 $\pm$ 1.85	66.7
I gained a stronger appreciation for the unity of humankind.			2.03 $\pm$ 1.76	69.2
I was inspired to express my creativity.			1.18 $\pm$ 1.54	48.7
I increased my involvement in political activities.			0.72 $\pm$ 1.05	38.5
I began to think that differences in political ideology are arbitrary.			0.67 $\pm$ 1.26	30.8
New Possibilities (PTGI)	0.77	1.84 $\pm$ 1.11		
New opportunities are available which wouldn't have been otherwise.			3.51 $\pm$ 1.39	94.9
I am able to do better things with my life.			1.87 $\pm$ 1.70	61.5
I developed new interests.			1.59 $\pm$ 1.62	61.5
I am more likely to try to change things which need it.			1.31 $\pm$ 1.52	56.4
I established a new path for my life.			0.90 $\pm$ 1.43	35.9
Appreciation of Life (PTGI)	0.82	1.79 $\pm$ 1.39		
I can better appreciate each day.			1.89 $\pm$ 1.74	66.7
I changed my priorities about what is important in life.			1.74 $\pm$ 1.55	66.7
I have a greater appreciation for the value of my own life.			1.59 $\pm$ 1.52	61.5
Personal Strength (PTGI)	0.78	1.69 $\pm$ 1.31		
I am better able to accept the way things work out.			1.85 $\pm$ 1.62	66.7
I know better that I can handle difficulties.			1.85 $\pm$ 1.71	66.7
I have a greater feeling of self-reliance.			1.59 $\pm$ 1.70	53.8
I discovered that I'm stronger than I thought I was.			1.46 $\pm$ 1.68	51.3
Relating to Others (PTGI)	0.91	1.30 $\pm$ 1.18		
I put more effort into my relationships.			1.59 $\pm$ 1.59	61.5
I have more compassion for others.			1.46 $\pm$ 1.50	59.0
I learned a great deal about how wonderful people are.			1.33 $\pm$ 1.48	53.8
I more clearly see that I can count on people in times of trouble.			1.33 $\pm$ 1.48	51.3
I have a greater sense of closeness with others.			1.31 $\pm$ 1.58	48.7
I better accept needing others.			1.13 $\pm$ 1.44	46.2
I am more willing to express my emotions.			0.97 $\pm$ 1.29	43.6
Spiritual Change (PTGI)	0.97	0.89 $\pm$ 1.43		
I have a better understanding of spiritual matters.			0.92 $\pm$ 1.49	33.3
I have a stronger religious faith.			0.85 $\pm$ 1.41	33.3
TOTAL	0.96	1.72 $\pm$ 0.99		

Note: PCST, then PTGI, subscales and their items are listed in descending order of the means. PCST = Positive Change from Space Travel; PTGI = Post-Traumatic Growth Inventory.

In the "changes in daily life" subscale, two of the original items ("I enhanced my career prospects" and "I became interested in extrasensory experiences like telepathy") were dropped in our final analyses because they had low ( $< 0.3$ ) item-total correlations. These items were not used in our final results (and do not appear in Table I) but they are still shown in the sample questionnaire online. The lower  $\alpha$  value for "changes in daily life" compared with the "perceptions of Earth" and "perceptions of space" subscales possibly resulted from the greater heterogeneity of the items in that subscale. The correlations between these three subscales ranged from 0.65 to 0.75.

To evaluate the construct validity of the eight subscales, we examined their inter-correlation. Overall, the pattern of correlations showed that the constructs were related to one another in the positive direction and were

not redundant with one another. On average, their inter-correlation was 0.64. The correlation matrix showed a reasonable pattern given the contents of the various scales. For example, the "perceptions of Earth" subscale was most strongly related to the "perceptions of space" subscale ( $r = 0.75$ ) and most weakly related to the PTGI "new possibilities" subscale ( $r = 0.48$ ). In sum, the psychometric analyses supported the instrument's internal validity and reliability.

## RESULTS

On the whole, the average amount of change reported by the 39 respondents was  $1.72 \pm 0.99$ , or between "a very small" and "a small" degree on the 0–5 Likert-like scale. Every respondent reported at least some change (total mean score  $> 0$ ), but the degree of

change varied widely (subject mean scores ranged from 0.44 to 4.39). The greatest change registered among subscales was within the “perceptions of Earth” subscale, which had the highest mean change score (mean = 2.94 ± 1.27; Table I). The “spiritual change” subscale had the lowest mean change score (mean = 0.89 ± 1.43).

A general linear model multivariate analysis showed that there was at least one significant difference between the eight subscales [Wilks’ Lambda = 0.194, F (7,32) = 19.02, p < 0.001]. Next, we conducted a set of seven ordered *t*-tests, comparing each mean to that of the next-highest mean, for our eight subscales. The highest score, “perceptions of Earth,” was significantly higher than the mean of the next highest subscale [“perceptions of space,” *t* (38) = 6.19, p < 0.001]. Similarly, the lowest score, “spiritual change,” was significantly lower than the next-lowest subscale [“relating to others,” *t* (38) = 2.34, p = 0.024]. If we apply a Bonferroni correction to reduce the possibility of Type I error, the threshold for statistical significance would be 0.007, using an  $\alpha$  of 0.05 for the set of seven tests. Therefore, using this stringent criterion, the “spiritual change” subscale would no longer be considered statistically significant.

Examining the item-level descriptive statistics shown in Table I, there were five items that were strongly endorsed, which we defined as an average mean change score of at least 2.5 (the midpoint of the scale). Three of these were from the “perceptions of Earth” subscale (appreciating Earth’s beauty, appreciating Earth’s fragility, treasuring the Earth). A fourth was from the “perceptions of space” subscale (sense of wonder about the universe), and the fifth was from the “new possibilities” subscale (new opportunities). Seven items had low mean change scores, which we defined as a mean ≤ 1, and these included both items in the “spiritual change” subscale. The last column of Table I shows the percent of the sample reporting each change (mean score > 0). Almost all items with the strongest average degree of change were also those most frequently endorsed as having changed. For example, the item with the greatest mean change score (“I gained a stronger appreciation of the Earth’s beauty”) was endorsed as having a change experienced by 38 of the 39 respondents (97.4%).

Approximately one-quarter of the respondents (10 out of 39) qualified at least 1 of their item scale scores with a 0\* to indicate that they were reporting no change because no further shift was possible for that characteristic (Table II). The item most frequently designated with 0\* was the PCST item “I became more excited about space exploration” followed by “I have a better understanding of spiritual matters” and “I have a stronger religious faith.” Some respondents who reported “no change” on the fixed-response questions made similar comments in the open-ended responses. Five of the eight respondents who provided general comments or feedback about the questionnaire (question #44), four of whom gave 0\* responses, spontaneously mentioned that their world-view or sense of self had been estab-

TABLE II. FREQUENCY OF ITEMS DESIGNATED WITH STARRED ZERO (0\*).

Items (paraphrased)	% of n = 39 respondents
I became more excited about space exploration.	15.4
I have a better understanding of spiritual matters.	10.3
I have a stronger religious faith.	10.3
I realized how much I treasure the Earth.	7.7
I gained...appreciation for...the Cosmos.	7.7
I gained a stronger sense of wonder about the universe.	7.7
I became interested in...life on other planets.	7.7
I put more effort into my relationships.	7.7
I learned to appreciate the fragility of the Earth.	5.1
I gained...appreciation for the unity of humankind.	5.1
My relationship with my family grew stronger.	5.1
I have a greater feeling of self-reliance.	5.1
I have a greater appreciation for the value of my own life.	5.1
I know better that I can handle difficulties.	5.1
I gained...appreciation of the Earth’s beauty.	2.6
I increased my involvement in environmental causes.	2.6
...differences in political ideology are arbitrary.	2.6
I changed my priorities...	2.6
...I can count on people...	2.6
I am more willing to express...emotion.	2.6
I am able to do better things with my life.	2.6
I learned...how wonderful people are.	2.6
I better accept needing others.	2.6

Note: There were n = 10 questionnaires with at least one such 0\* response.

lished long before their mission and was fundamentally unchanged by their space experience.

We systematically coded and analyzed the 32 sets of responses that we received for the open-ended items addressing positive experiences (question #37, “I experienced a positive change not addressed in the above items. Please describe this change here and rate it as in the above items” and #38, “Select the most powerful positive experience you had in space and describe it below”). We decided to combine the data from these two items and analyze them all together, because respondents who answered both questions expressed the same ideas in both. Question #38 was answered by 31 respondents, four of whom also answered #37. An additional respondent answered #37 but not #38. By consensus of the authors, the themes that emerged on examining the subjective response material were: observations of Earth (16 of the 32 respondents mentioned this theme; e.g., “seeing how fragile it really is”), teamwork/camaraderie (9 responses; e.g., “being part of a great team”), existential understanding (9 responses; e.g., “greater sense of what’s important”), achievement/accomplishment (7 responses; e.g., “do something difficult and be successful at it”), satisfaction (3 responses; e.g., “more relaxed, content”), human unity (2 responses; e.g., “the brotherhood of all humanity”), spiritual (2 responses; e.g., “we serve a powerful and loving God”), and wonderment not related to viewing Earth (1 response). This list totals more than 32 because some respondents mentioned more than 1 theme.

In addition, we analyzed question #44, “If you have any comments you would like to add, please do so

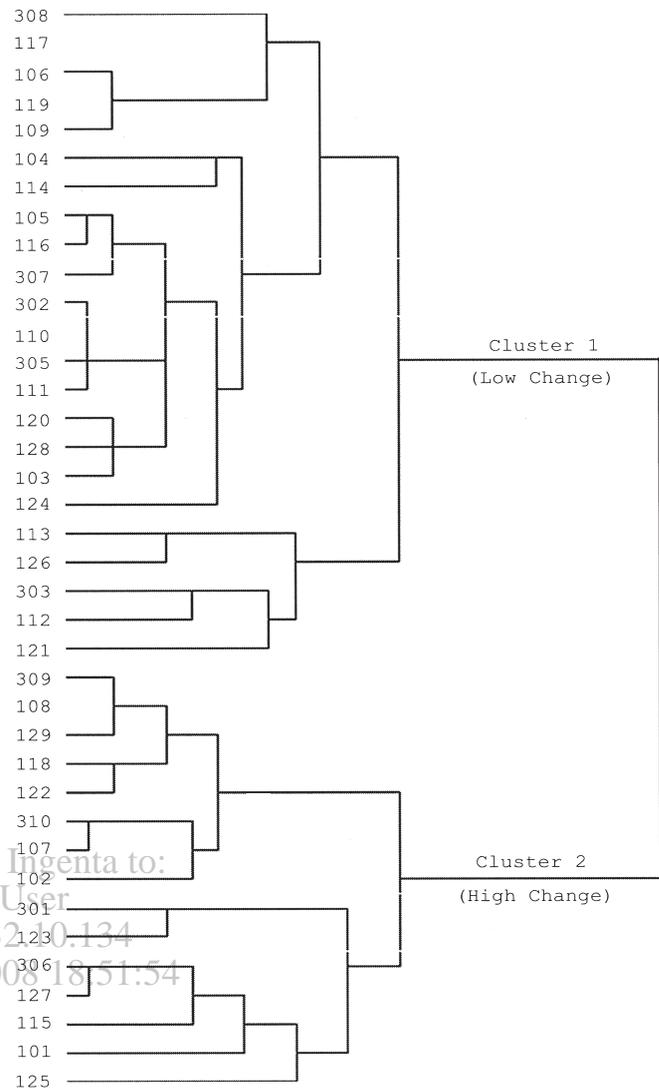
below.” The predominant theme emerging from responses to question #44 was that the questionnaire did not take into consideration the possibility that no change or negative effects could have occurred from being in space. Indeed, five of the eight responses to question #44 focused on this theme (two responses were additional positive reactions to being in space, and one offered suggestions for improving the questionnaire). This theme is consistent with the 0\* responses reported above.

We were interested in determining whether changes would typically occur in attitudes, behaviors, or both. By consensus of the authors, we categorized the items of our questionnaire as “attitude” if they represented an internal experience (thought or feeling state) or “behavior” if they represented an external process or activity. This differentiation resulted in 26 “attitude” items (e.g., “I realized how much I treasure the Earth,” “I have a greater sense of closeness with others”) and 10 “behavior” items (e.g., “I increased my involvement in environmental causes,” “I am more willing to express my emotions”). For attitude items, the mean change was  $1.70 \pm 1.03$ , and for behavior items it was  $1.78 \pm 1.00$ . Thus, there was no difference in the amount of change endorsed in either category (paired samples  $t = -0.90$ ,  $p = 0.38$ ), meaning that respondents endorsed positive changes in attitude and behavior to similar degrees.

We predicted that changes in attitude would be associated with changes in behavior. At the most general level, attitude and behavior changes were strongly correlated ( $r = 0.84$ ,  $p < 0.001$ ). Focusing on individual PCST items, we had five a priori predictions, four of which were supported. Three of these items related to positive attitudes toward Earth, and, as predicted, these were associated with the behavior item “I increased my involvement in environmental causes” (“I realized how much I treasure the Earth,”  $r = 0.58$ ,  $p < 0.001$ ; “I learned to appreciate the fragility of the Earth,”  $r = 0.66$ ,  $p < 0.001$ ; “I gained a stronger appreciation of the Earth’s beauty,”  $r = 0.38$ ,  $p < 0.05$ ). The fourth item, “I gained a stronger understanding of the unity of humankind,” was also associated with the predicted behavior item “My relationship with my family grew stronger” ( $r = 0.35$ ,  $p < 0.05$ ). However, our last prediction was not borne out: the “unity of humankind” attitude was not associated with the behavior item “I increased my involvement in political activities” ( $r = 0.18$ ,  $p = 0.29$ ).

We sought to determine whether changes were distributed differently across different demographic groups. There were no statistically significant differences in any of the above results between gender, nationality/culture, number of missions flown, or days spent in space for any aspect of the questionnaire, as determined by mean change scores (be it individual items, the PCST group of items, the PTGI group of items, the eight different subscales, or the entire questionnaire as a whole). (Results not shown but available.)

As a further exploration into the possibility that different types of people could have different patterns of positive response to the experience of spaceflight, we used a data-driven, cluster analysis approach to search for groups of respondents with different response pro-



**Fig. 1.** Dendrogram showing two main clusters of respondents. The left column shows the respondent code number, and the pattern on the right represents the distance in multidimensional space between each respondent and all the other respondents. The branching pattern shows two clusters of respondents. (There was originally one outlier forming a third group, which was removed from this figure and was not included in the analyses.) Cluster 1 is at the top and contains 23 respondents, while cluster 2 is at the bottom and contains 15 respondents.

files. In this approach, we calculated the standardized Euclidean distances between persons in multi-dimensional space using dimensions that corresponded to the responses on the 13 space-specific (PCST) items. We chose only these items in order to group respondents on the basis of their responses about their space experience. This analysis generated the dendrogram shown in **Fig. 1**.

The branching pattern revealed that respondents segregated into two clusters (with one outlier, which was removed) based on their pattern of responses to the PCST items. We examined the characteristics of these two clusters of respondents, which had been identified using the above analysis, to determine more substantively what distinguished these clusters. For this subsequent analysis, all available data were considered. Cluster 1 ( $n = 23$ ) did not differ from cluster 2 ( $n = 15$ ) on

TABLE III. COMPARISON OF CLUSTERS.

Subscale	Cluster 1 (n = 23)		Cluster 2 (n = 15)	
	Rank	Mean ± SD	Rank	Mean ± SD
Perceptions of Earth	1	2.23 ± 1.03	1	4.02 ± 0.81
Perceptions of Space	5	0.97 ± 0.68	2	3.47 ± 0.85
Changes in Daily Life	7	0.72 ± 0.58	6	2.17 ± 0.83
New Possibilities	6	0.81 ± 0.99	8	2.01 ± 1.14
Appreciation of Life	2	1.50 ± 1.07	5	2.37 ± 1.01
Personal Strength	4	1.10 ± 1.15	4	2.62 ± 1.03
Relating to Others	8	0.13 ± 0.34	7	2.10 ± 1.67
Spiritual Change	3	1.12 ± 0.94	3	2.82 ± 1.40
TOTAL		1.13 ± 0.59		2.61 ± 0.82

any of the available demographic or mission characteristics, nor on the frequency of themes contained in the open-ended items. There appeared to be two main features that distinguished the two clusters (**Table III**).

First, they differed in their reactivity to the questionnaire items. Using *t*-tests, cluster 2 reported a significantly greater degree of change on the total score ( $p < 0.001$ ), on all 8 subscales ( $p < 0.05$ ), and on most of the individual items (12 of the 13 PCST items and 14 of the 21 PTGI items, all  $p < 0.05$ ). The differences for the remaining one PCST item (question #14) and seven PTGI items (questions #18, 22, 23, 26, 29, 35, 36) were in the same direction but not statistically significant (*t*-tests, details not shown but available). Second, the two clusters appeared to have different profiles in terms of the rank order of change endorsed for each of the eight subscales. After the “perceptions of Earth” subscale, which was the highest in both groups, the ranking of the other types of changes were quite different. Ranked as the second-strongest type of change for the more reactive (“high change”) group was “perceptions of space,” which included items such as a heightened sense of wonder about the universe, more excitement about space exploration, and a new appreciation for the boundlessness of the cosmos. This subscale was rated only fifth in importance by the less reactive (“low change”) group. The less reactive group was more focused on changes involving their inner life (“appreciation of life” subscale), such as changing their priorities, better appreciating each day, and appreciating the value of their life overall—these changes were rated second by them but only fifth by the more reactive group.

## DISCUSSION

The results of our study suggest that space travel is a meaningful experience whose effects endure for some time postflight. Every respondent had a positive reaction to being in space, but the reactions differed in their intensity. The experiences that were reported most frequently, and with the highest degree of change, were those encapsulated in the “perceptions of Earth” subscale. The item “I gained a stronger appreciation of the Earth’s beauty” had the highest mean score (and one of the lowest SD) of all the individual items, with the average rating indicating a “great degree” of change. One reason why this subscale ranked significantly higher than any of the others may have been due to the

fact that people working in space develop a new view of their home planet, both literally and figuratively. Reports about reactions to the Earth from space describe increases in visual and auditory perceptual acuity during spaceflight (6,9,14), and various astronauts have commented on the intensity of the colors of our planet against the black backdrop of the universe (11,26). Our findings that respondents gained a stronger appreciation for the beauty and fragility of the Earth are consistent with these reports.

The importance of perceptions of Earth might impact on the crew of an expeditionary-type mission (such as a flight to Mars) when the Earth becomes imperceptible due to the vast distances involved. As discussed by Kanas and Manzey (9, p. 186), this “Earth-out-of-view” phenomenon may affect the psychological status of the expeditionary crew. For example, crewmembers may become anxious, depressed, or homesick as feelings of isolation intensify. Perhaps onboard videos or pictures of the Earth that were taken from other on-orbit missions could be comforting for these pioneers who cannot view the Earth. Previous work with polar explorers (finding that they decorate their habitation capsules with images of warmer climates) suggests that this intervention could prove useful (23). Also, other celestial objects have their own beauty and may potentially compensate for the loss of viewing their now-distant home planet.

No other subscales resonated as strongly with the respondents as did “perceptions of Earth.” Although respondents endorsed positive changes in all of the seven other subscales, these changes were rated on average as between “very small” and “small.” The low scores for these items may reflect a reluctance of the respondents to reveal themselves or a tendency to report only what was believed to be expected or acceptable; this could be the case for items least often endorsed (e.g., those items addressing issues of spirituality). This is a limitation of data obtained from self-reports; it is difficult to determine whether the responses or the experiences themselves were of limited intensity. Additionally, it is likely that the respondents’ experiences in space reinforced previously held views, and this characteristic was difficult to assess in a questionnaire designed to measure change. Indeed, many of the items were given a 0\* score, suggesting that some views were already strongly held and that there was no room for the spaceflight experience to cause further change. Finally, it is possible that the respondents’ experience in space was personally meaningful but did not lead them to change their attitudes or behaviors to any great degree.

We were surprised by the relative dearth of spirituality-related responses, given the prominence that spirituality has played in some anecdotal reports about reactions to being in space (8,11,26), as well as research that suggests that positive life experiences can be interpreted as mystical or religious (27). The published study that is the most similar to ours also found a surprisingly low absolute rate of spirituality-related material (24), despite a relative increase experienced postflight. Although being in space may have been

affirming and transcendent, it may not have been commonly experienced as being spiritual in nature by our respondents. It is possible that “spirituality” is too loaded or specific an idea, and instead a concept such as “transcendence” or “existential understanding” (as noted in a number of subjective responses) would have corresponded better with the way that many of the respondents think about their experience. Comments from the qualitative items of the questionnaire suggested that the view of Earth from orbit inspired a sense of awe and wonder that made a powerful, but not necessarily spiritual, impression. It also suggested that our respondents were expressing an appreciation for the familiar comfort of a natural environment sought out from a space habitat that may have been perceived to be confining and sterile.

Positive experiences may have been affirming and reinforcing without necessarily leading to a change in behaviors or attitudes. A number of comments emphasized that respondents had established their values long before their missions and that these values were not prone to change as a result of any one life experience. On the other hand, many respondents did report changes in both attitudes and behaviors. Some of our predictions about the relationships between attitudes and behaviors were supported by the data. Although an enhanced appreciation for human unity did not typically translate into greater enthusiasm for politics (as it did for stronger family ties), it was clear that an enhanced appreciation for the fragility of Earth—not just its beauty—often brought with it a greater enthusiasm for environmental causes. These results raise issues of what makes an individual act on his or her experiences and also how people’s experiences can be even more enriching if their behaviors were altered based on their changed outlook. Perhaps a willingness to embrace and enact change brought about by positive experiences could help maintain the morale of long-duration space crewmembers and help with their postflight re-adjustment to society. This could be a fruitful direction for training countermeasures or postflight supportive debriefings.

Although no statistically significant differences between demographic groups could be found, cluster analysis did reveal differences between respondents (at least as far as response characteristics were concerned). Our dendrogram showed two patterns of response to the spaceflight experience based on the PCST subscales of our questionnaire. These high change/low change groups were distinguished by how they reacted to their experience in space as well as their ranking of different PCST items (but not by their amount of time in space, as we had hypothesized). The difference in the relative importance of change may be due to differences in personality or cognitive styles (e.g., reactivity vs. relative insensitivity to experiences or differences in emotional expressiveness) and needs to be explored further. It is also possible that other demographic variables may have contributed to differences in degree of change experienced by the respondents. For example, respondents for whom there was a long interim between their last mission in space and their receiving the question-

naire may have had a more positive recall bias when providing responses to the questionnaire.

These differences may affect coping styles and might become important in a proposed mission to Mars, when the Earth’s beauty is no longer appreciable or immediately inspiring. Because the view of Earth has been such a central feature of the space experience to date, it will clearly be a dramatically different experience for crewmembers when that view is no longer available on the journey to Mars. Perhaps the more reactive high change group might find more solace and inspiration from the perceptions of space than the less reactive low change group since they rated changes in this factor as being second to their perceptions of Earth. However, the vastness of the cosmos would not be the same source of inspiration for the less reactive group, who instead might benefit from more interpersonal interventions, such as more frequent correspondence with family members.

It is important to note that these results and interpretations must be considered tentative given the small sample size and the potential for a self-selection bias in the composition of our respondent dataset. Participation in this study was not compulsory, and the response rate was low, so it is possible that the respondents were not representative of their total population. Perhaps those with specific points to make or with certain personality characteristics may have been more inclined to participate than others. It is also possible that those spacefarers responsible for the anecdotal literature that influenced the questionnaire items were unique and not representative of the overall population of the astronauts and cosmonauts. Thus, there might have been other important positive changes that we did not address in our study, although our results did not indicate the presence of other salutogenic issues that we did not consider. The themes addressed in the PCST and PTGI items were compatible with those responses given for the open-ended questions (except for not taking into consideration the possibility of negative or no changes).

This study is the first to directly and systematically query astronauts and cosmonauts about the salutogenic effects of their spaceflight experience. The results of our study suggest that individuals may vary in their specific positive reactions to spaceflight, but these reactions can provide clues about how future space travelers can optimize their mental health and personal growth during and after their missions. Additionally, such studies can help to educate the public about the allure and excitement of space travel. Future studies (which should include more women and additional measures of positive effects) should try to assess how positive experiences can be employed to help space travelers mobilize internal resources in order to maintain morale during extended missions. Knowledge from such studies could then be applied to develop countermeasures to enhance well-being and to counteract negative psychological sequelae during future long-duration space missions, as well as to help spacefarers reintegrate better into society on their return home.

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APPENDIX A. STUDY QUESTIONNAIRE.

Indicate for each of the statements below the degree to which a positive change occurred in your life as a result of your being in space, using the following scale. If you select "0" and the reason is that you felt so strongly before being in space that there was no room to change, please mark your "0" with a star (e.g., 0\*).

- 0 = I did *not* experience this change as a result of my being in space.  
 1 = I experienced this change to a *very small* degree as a result of my being in space.  
 2 = I experienced this change to a *small* degree as a result of my being in space.  
 3 = I experienced this change to a *moderate* degree as a result of my being in space.  
 4 = I experienced this change to a *great* degree as a result of my being in space.  
 5 = I experienced this change to a *very great* degree as a result of my being in space.
- 1) I enhanced my career prospects. \_\_\_\_\_
  - 2) I realized how much I treasure the Earth. \_\_\_\_\_
  - 3) I increased my involvement in political activities. \_\_\_\_\_
  - 4) I gained a new appreciation for the boundlessness of the Cosmos. \_\_\_\_\_
  - 5) I became more excited about space exploration. \_\_\_\_\_
  - 6) I gained a stronger sense of wonder about the universe. \_\_\_\_\_
  - 7) I learned to appreciate the fragility of the Earth. \_\_\_\_\_
  - 8) I gained a stronger appreciation of the Earth's beauty. \_\_\_\_\_
  - 9) I increased my involvement in environmental causes. \_\_\_\_\_
  - 10) I gained a stronger understanding of the unity of humankind. \_\_\_\_\_
  - 11) My relationship with my family grew stronger. \_\_\_\_\_
  - 12) I was inspired to express my creativity. \_\_\_\_\_
  - 13) I became interested in extrasensory experiences like telepathy. \_\_\_\_\_
  - 14) I began to think that differences in political ideology are arbitrary. \_\_\_\_\_
  - 15) I became more interested in the possibility of life on other planets. \_\_\_\_\_
  - 16) I changed my priorities about what is important in life. \_\_\_\_\_

- 17) I have a greater appreciation for the value of my own life. \_\_\_\_\_
- 18) I developed new interests. \_\_\_\_\_
- 19) I have a greater feeling of self-reliance. \_\_\_\_\_
- 20) I have a better understanding of spiritual matters. \_\_\_\_\_
- 21) I more clearly see that I can count on people in times of trouble. \_\_\_\_\_
- 22) I established a new path for my life. \_\_\_\_\_
- 23) I have a greater sense of closeness with others. \_\_\_\_\_
- 24) I am more willing to express my emotions. \_\_\_\_\_
- 25) I know better that I can handle difficulties. \_\_\_\_\_
- 26) I am able to do better things with my life. \_\_\_\_\_
- 27) I am better able to accept the way things work out. \_\_\_\_\_
- 28) I can better appreciate each day. \_\_\_\_\_
- 29) New opportunities are available which wouldn't have been otherwise. \_\_\_\_\_
- 30) I have more compassion for others. \_\_\_\_\_
- 31) I put more effort into my relationships. \_\_\_\_\_
- 32) I am more likely to try to change things which need changing. \_\_\_\_\_
- 33) I have a stronger religious faith. \_\_\_\_\_
- 34) I discovered that I'm stronger than I thought I was. \_\_\_\_\_
- 35) I learned a great deal about how wonderful people are. \_\_\_\_\_
- 36) I better accept needing others. \_\_\_\_\_
- 37) I experienced a positive change not addressed in the above items. (Please describe this change here and rate it as in the above items.) \_\_\_\_\_
- 38) Select the most powerful positive experience you had in space and describe it below.
- 39) Please estimate the total number of days you have spent in space: \_\_\_\_\_ days
- 40) Number of missions you have flown that lasted less than 1 month: \_\_\_\_\_
- 41) Number of missions you have flown that lasted 1 month or more: \_\_\_\_\_
- 42) Your nationality: \_\_\_\_\_
- 43) Your gender: \_\_\_\_\_
- 44) If you have any comments you would like to add, please do so below: \_\_\_\_\_