

Personality Characteristics and Trait Clusters in Final Stage Astronaut Selection

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Introduction: This paper presents personality testing data from final stage applicants to the NASA astronaut program. Questions addressed include whether personality predicted final selection into the astronaut corps, whether women and men demonstrated typical gender differences in personality, and whether three characteristic clusters found in other high performance populations replicated in this group. **Methods:** Between 1989 and 1995, 259 final stage astronauts completed the Personal Characteristic Inventory (PCI) which assesses personality characteristics related to the broad traits of Instrumentality and Expressivity. In addition, 147 of these individuals also completed an abbreviated version of the NEO Five Factor Inventory (NEO-FFI) which assesses the "Big Five" traits of Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. **Results:** Three previously identified trait clusters (Right, Wrong, and No Stuff) were found to replicate in this population. No differences were found on the PCI or on the modified NEO-FFI between applicants who were chosen to become astronauts ($n = 63$) and those who were not ($n = 196$). Men scored higher than women on competitiveness, but lower on expressivity and achievement strivings. **Discussion:** These analyses suggest that the "Right Stuff," "Wrong Stuff" and "No Stuff" clusters originally described in airline pilots and other high performance groups also exist within this population. Consistent with findings from other high performance populations, men and women tend to differ to a lesser extent than found in the general population, particularly on traits related to achievement motivation. Personality trait testing did not predict which applicants were most likely to be accepted into the astronaut corps.

Keywords: human factors, spaceflight, personality traits, psychology.

THE USE OF PERSONALITY assessment has been recognized by space agencies and researchers as one important approach to identifying candidates who are likely to perform and adapt optimally during space missions (1,6,30). Over the past two decades, a number of studies have shown that individuals who demonstrate superior performance and higher levels of coping under conditions of isolation and confinement share certain characteristics that differentiate them from those who do not (22,23,27). The majority of this research has utilized one of two personality batteries, either the Personal Characteristic Inventory (PCI), developed by Helmreich (8,14,15,24) or the NEO Personality Inventory (NEO-PI) developed by Costa and McCrae (4). A shorter form of the NEO-PI, the NEO Five Factor Inventory (or NEO-FFI), is also available. The inter-relationships between the PCI and the NEO-PI/NEO-FFI are not well documented, making it difficult to compare and summarize results from these two lines of research.

The PCI aims to capture positive and negative aspects of two core dimensions of personality: Instrumentality and Expressivity. Instrumental traits refer to overall goal seeking and achievement motivation while expressive traits are related to interpersonal sensitivity and concern. The scales of the PCI have their origins in the gender and performance research of Spence and Helmreich and have shown utility in predicting performance in a number of domains (9,34). Cluster analyses on PCI scores from military and commercial airline pilots have identified frequently occurring combinations of traits that differentially predict performance in the multi-crew aviation environment (3,7). Subsequent research has confirmed that these combinations of traits are also predictive of performance in a variety of other confined and hazardous settings, including spaceflight (25), simulated spaceflight (28), and military training (29). Superior performance has consistently been linked to a personality profile characterized by a combination of high levels of instrumentality and expressivity along with lower levels of interpersonal aggressiveness. This personality profile has sometimes been referred to as the "Right Stuff," suggesting that this is the ideal description for an effective astronaut or pilot.* Inferior performance has been linked to personality profiles typified by a hostile and competitive interpersonal orientation (the "Wrong Stuff," suggesting that these individuals may not have the best characteristics for teamwork in complex settings) or to low achievement motivation combined with passive-aggressive characteristics (the "No Stuff" cluster, referring to individuals who score uniformly low on key traits). Of particular relevance to the space program, these profiles have been shown to

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*This reference to the "Right Stuff" is somewhat of a play on the title of Tom Wolfe's account of the early Mercury Astronaut program entitled *The Right Stuff* (38).

predict receptivity to Crew Resource Management (CRM) training among pilots (10). The latter finding is particularly significant given that CRM training has been identified as a key means to improve crew coordination in multinational crews and is already employed in the training of shuttle and International Space Station astronauts (11,20).

The NEO-PI is a widely utilized battery that assesses the Big Five personality factors of Extraversion, Conscientiousness, Agreeableness, Neuroticism (also known as Emotional Stability or Adjustment), and Openness to New Experience (4). During the past two decades, a large body of literature has validated the Big Five as predictors of performance across organizational employment settings (18,37), as well as in isolated and confined environments (21,36). For example, in an analysis of data collected over an 11-yr period involving Antarctic personnel, Palinkas et al. (21) found that low levels of Neuroticism, Extraversion and Conscientiousness were predictive of more than one performance measure in that environment. The Big Five model can incorporate a number of other personality theories, suggesting that it provides a useful general framework for viewing human behavior (5).

Rationales for using personality measures in the selection of astronauts need to be balanced with the potential benefits they add to the existing selection process. Even if personality criteria are not formalized, self-selection together with formal selection will ultimately result in increased homogeneity of people belonging to the same organization in terms of personality characteristics (31). This may again be reflected in professional cultures and stereotypes (12). Along this line, McFadden et al. (17) found that expressive traits were significantly associated with astronaut effectiveness in tasks involving teamwork (or "group living"), whereas instrumental traits had low predictive validity. While this population was characterized by high variability on measures of expressivity, scores on scales assessing instrumentality were uniformly high and variability on this trait was reduced as a result. The investigators attributed the latter finding to the highly screened nature of the astronaut corps, and in particular to excellence in academic and job performance prior to becoming astronauts. They commented that astronauts are not as highly screened on interpersonal skills as they are on past achievements. These findings further suggest that traits typical for current astronauts more closely approximate traditionally male stereotypes in personality as opposed to female ones (33). The implications of this on both attraction to and selection into the astronaut corps are unclear. The question of gender differences, including differences in personality traits, and their implications for performance among astronauts remain largely unexplored issues.

This paper reports data from final stage NASA astronaut applicants between 1989 and 1995, collected as part of a long-term study into astronaut personality and performance. During this process, all applicants completed either the PCI alone or the PCI along with an abbreviated version of the NEO-FFI. These data provide the opportunity to examine the inter-relationship be-

tween these two instruments and to examine whether the PCI personality clusters replicate in an astronaut population. This paper also compares the personality testing results of selected astronauts and non-selected applicants in order to gain an understanding of whether personality traits were determining factors in the final stage of the selection. Earlier studies have investigated the relationship between personality traits and peer, supervisory, and objective assessments of performance among active astronauts (17,25,26). A key finding from those studies was the identification of four personality traits that were related to astronaut effectiveness, four of which related to interpersonal concern and sensitivity. Though these findings were intriguing, they were limited by sample size and methodological restraints, and the authors suggested that follow-up and long-term studies should be conducted to further explore these issues. The data obtained from astronaut applicants in 1989–1995 and presented herein have not been previously reported.

METHODS

Participants

The subjects participating in this study were candidates from three successive astronaut selections conducted by NASA. Typically, NASA invites applications for astronauts every 2 yr. This generally results in between 2000 and 4000 applications being submitted from across the U.S. each time the opportunity to apply is announced. For each wave of applications, approximately 110 individuals are invited to the Johnson Space Center (JSC) in Houston for further evaluation. This initial selection evaluates prior medical history, educational qualifications, and/or demonstrated proficiency in operating high performance aircraft (30). From the 110 or so who are invited to JSC, approximately 20 will be selected as astronauts.

In 1990, 106 applicants were brought to JSC for evaluation (chosen from 1945 applicants); in 1992, 87 were brought to JSC (chosen from 2054 applicants); and in 1994, 122 were invited to JSC (chosen from 2962 qualified applicants). All 315 applicants were offered the opportunity to participate in this study, and all agreed to take part. However, due to competing activities during their brief time at JSC, some of the candidates were not able to complete the assessment battery. A total of 259 applicants (46 female, 213 male) were able to complete the study, which represents a participation rate of 82%. There were no systematic or voluntary participant dropouts recorded by the investigators during the testing sessions.

Of the astronaut applicants assessed in this study, a total of 63 (12 female, 51 male) were eventually successful in their application to become astronauts. An additional six applicants were selected to be astronauts who were not able to participate in the study. It is important to note the Astronaut Selection Board did use some psychological assessment in choosing these 63 individuals with the purpose of "selecting out" those individuals with psychopathology that was considered disqualifying for flight personnel. This process is detailed

TABLE I. DEFINITION AND CRONBACH'S ALPHAS FOR THE SCALES OF THE PERSONAL CHARACTERISTICS INVENTORY AND THE ABBREVIATED NEO-FIVE FACTOR INVENTORY.

PCI scales	Definitions	Number of items	Alpha*
Instrumentality	Refers to overall goal seeking and achievement motivation.	8	0.80
Expressivity	A measure of interpersonal orientation, sensitivity, and concern.	8	0.72
Verbal Aggressiveness	Traits associated with a type of critical, verbal negativity.	4	0.59
Negative Communion	Traits associated with a lack of instrumentality (weak, shy, submissive, etc.).	4	0.41
Negative Instrumentality	Traits associated with a negative form of goal seeking, such as being arrogant, dictatorial, etc.	8	0.75
Mastery	A more focused measure of achievement motivation reflecting a need to undertake and master new and challenging activities.	8	0.65
Work Orientation	Reflects a desire to work hard.	6	0.75
Competitiveness	Reflects a desire to succeed in competitive interpersonal situations.	5	0.73
Achievement Strivings	Traits associated with taking work seriously and working hard.	6	0.76
Impatience/Irritability	Reflects a sense of time urgency and impatience associated with a high degree of irritability.	6	0.40
Abbreviated NEO-FFI scales	Definitions [†]	Number of items	Alpha [‡]
Neuroticism	The tendency to experience nervousness, tension, anxiety, emotional instability, hostility, and sadness.	8	0.87
Extraversion	An energetic approach to the external world, including sociability, assertiveness, and positive emotionality.	8	0.68
Openness to new experience	Describes the breadth, depth, originality, and complexity of an individual's mental and experiential life.	8	0.66
Agreeableness	The quality of one's interpersonal interactions along a continuum from compassion and altruism to antagonism.	8	0.72
Conscientiousness	Persistence, organization, and motivation in goal-directed behaviors, and socially prescribed impulse control.	8	0.86

*Cronbach's alpha for the PCI scales based upon an aggregate sample of 924 respondents.

[†]Adapted from John and Srivastata, 1998 (16).

[‡]These sample correlations are based upon samples of 546 respondents (N, E) and 810 respondents (O, A, C) in an ongoing study into relationships between the PCI and the NEO-FFI.

in Santy (30) and involves clinical interviews and the administration of several standardized tests, including the Minnesota Multiphasic Personality Inventory (MMPI), Multidimensional Aptitude Battery (MAB), Forer Structured Sentence Completion Test (FSSCT, a projective test), and the Millon Clinical Multiaxial Inventory (MCMI-II). Santy (30) reports that 9 out of 106 finalist applicants during the 1989–1990 selection period (the first of the three applicant groups included in this study) were disqualified by such testing, suggesting a disqualification rate of less than 10%. Many more applicants were disqualified for medical reasons, and it is possible some of those individuals also had disqualifying psychological assessments, so the estimate of 10% for psychiatric/psychological disqualification may be underrepresentative.

Instruments

The Personal Characteristics Inventory (PCI) is a multi-axial personality trait assessment battery. It is a paper-and-pencil self report questionnaire designed primarily for research into traits and performance. The version of the battery used in this study consisted of 225

questions, with each item answered on a five-point Likert scale, and required approximately 40 min to complete. The core of the PCI consists of 11 scales that assess various aspects of the broad traits of Instrumentality and Expressivity. These scales have been taken from three pre-existing assessment instruments—the Extended Personal Attributes Questionnaire (EPAQ) (14), the Work and Family Orientation Questionnaire (WOFO) (8), and the Jenkins Activity Survey (JAS) (15,24). These personality scales, their definitions and their internal consistencies, are listed in **Table I**. Additional scales were included in this version of the PCI that were not assessed in this study.

The abbreviated version of NEO Five Factor Inventory (NEO-FFI) used in this study is a self report battery designed to assess the “Big Five” traits of Neuroticism (N), Extraversion (E), Openness (O), Agreeableness (A), and Conscientiousness (C) (4). Measurement of the Big Five is possible using a number of instruments, of which the most standard is the revised NEO Personality Inventory (NEO PI-R), an extensive 240-item self report personality battery (4). The NEO-FFI is a short-form of the NEO PI-R and is comprised of 60 items, each of

which is answered on five-point scale ranging from "Strongly Agree" to "Strongly Disagree." For the assessment of astronaut applicants in the period from 1992 to 1995, five experimental 8-item scales were added to the personality testing battery in order to assess the Big Five. These scales were adapted from the 12-item scales of the NEO FFI. Significant restrictions on available testing time precluded the use of the full NEO-FFI or the even longer NEO-PI-R, and necessitated the reduction in the length. Since applicants during the period from 1989 to 1990 did not complete this version of the battery, Big Five data were collected from only 147 of the 259 applicants in this study. Subsequent studies of the psychometric properties of these 8-item scales suggest that they are both reliable and highly correlated with their parent scales. Based on a sample of 344 research volunteers, Pearson product-moment correlations between the experimental 8-item scales and the parent 12-item scales were as follows: Neuroticism $r = 0.85$, Extraversion, $r = 0.81$, Openness $r = 0.85$, Agreeableness $r = 0.81$, and for Conscientiousness $r = 0.90$ (19). Definitions and internal consistencies for these scales are listed in Table I.

Procedure

The study protocol was approved in advance by the Institutional Review Board (IRB) at The University of Texas at Austin. Each subject provided written informed consent before participating. Applicants who completed the batteries were informed that their participation was voluntary, that choosing not to participate would not affect the astronaut selection process, that data collected would not be used in the astronaut selection process, and that testing results would not be made available to NASA for selection purposes or in any future assessments. They were also informed that these data were to be used only by the principal investigator (Robert Helmreich, University of Texas at Austin) and his designated research associates, would be housed offsite at an academic institution, and would not be made available to NASA management at any time.

Statistics

All analyses were conducted by using SPSS 11.0 for Windows (35). Cronbach's alpha was used to evaluate the internal consistency of the scales used in this study, with an alpha of 0.60 set as the minimum for inclusion in the analysis. Two-tailed tests were used in all analyses and a significance level of $p < 0.05$ was chosen for this study, though actual p values are also reported.

RESULTS

Cluster Analyses

A cluster analysis was performed on PCI data collected from the 259 astronaut applicants. Cluster identification followed the same procedure as in the study by Gregorich et al. (7) and by Chidester et al. (3). To test the possibility of replicating these clusters, a total of three clusters along with the same seven scales speci-

TABLE II. STANDARDIZED MEANS FOR PERSONALITY SCALES FOR CLUSTERS IDENTIFIED AMONG ASTRONAUT APPLICANTS COMPARED WITH CLUSTERS PREVIOUSLY DESCRIBED FOR PILOTS (2).

	Clusters		
	Negative Instrumental	Positive Expressive/ Instrumental	Low Motivation
Astronaut Applicants			
Instrumentality	0.38	0.31	-0.89
Expressivity	-0.55	0.59	-0.16
Negative Instrumentality	0.84	-0.73	0.01
Verbal Aggressiveness	0.49	-0.63	0.31
Mastery	0.21	0.49	-0.93
Work Orientation	0.28	0.39	-0.88
Competitiveness	0.67	-0.23	-0.46
Commercial Pilots*			
Instrumentality	0.62	0.11	-0.85
Expressivity	-0.23	0.63	-0.34
Negative Instrumentality	0.75	-0.91	0.13
Verbal Aggressiveness	0.46	-0.72	0.27
Mastery	0.52	0.22	-0.85
Work Orientation	0.21	0.59	-0.91
Competitiveness	0.65	-0.19	-0.55
Relative frequencies			
Successful applicants	34.9%	38.1%	27.0%
Unsuccessful applicants	32.0%	39.0%	28.7%
Commercial Airline Pilots*	35.8%	33.9%	30.3%

*From Chidester and Foushee, 1991 (2).

fied by Gregorich and Chidester were submitted to the analysis: Instrumentality, Expressivity, Negative Instrumentality, Verbal Aggressiveness, Mastery, Work, and Competitiveness. The personality scales were transformed into standardized scores before conducting the cluster analysis. The K-means cluster algorithm suggested the presence of three clusters corresponding closely to those identified in the pilot samples. Consistent with previous studies, these clusters were labeled Negative Instrumental, Positive Instrumental/Expressive, and Low Motivation. Table II displays the mean standardized scores for the personality scales of individuals classified in each of the three clusters. The relative frequencies of subjects classified in each cluster are also shown in Table II. The first cluster, corresponding to what has been labeled Negative Instrumental (or "Wrong Stuff"), is marked by above average scores on Competitiveness, Negative Instrumentality, and Positive Instrumentality and below average scores on Positive Expressivity. A second cluster, corresponding to what has been labeled Positive Instrumental/Expressive (or "Right Stuff"), is marked by above average levels of Instrumentality, Expressivity, Mastery, and Work, and below average levels of Negative Instrumentality, Competitiveness, and Verbal Aggressiveness. The third cluster, corresponding to what has been labeled Low Motivation (or "No Stuff"), is characterized by below average scores on all scales with the exception of Negative Instrumentality and Verbal Aggressiveness which have slight elevations.

A Chi-squared test was used to investigate differences in cluster distribution among the successful and unsuccessful applicants. As shown in Table II, the fre-

TABLE III. CORRELATIONS BETWEEN SCALES OF THE PCI AND THE ABBREVIATED SCALES FROM THE NEO-FFI AMONG ASTRONAUT APPLICANTS (N = 147).

Scales	Neuroticism	Extraversion	Openness to Experience	Agreeableness	Conscientiousness
Instrumentality	-0.39**	0.25**	0.13	-0.09	0.42**
Expressivity	0.03	0.16	0.22**	0.50**	0.12**
Negative Instrumentality	0.13	0.07	-0.11	-0.54**	-0.18*
Verbal Aggressiveness	0.27**	-0.05	-0.04	-0.27**	-0.29**
Mastery	-0.24**	0.33**	0.27**	0.00	0.32**
Work Orientation	-0.22**	0.22**	0.15	0.03	0.29**
Competitiveness	0.09	-0.06	-0.21*	-0.39**	-0.08
Achievement Strivings	-0.20*	0.26**	0.10	-0.03	0.43**

Correlations are significant at the **0.01 level (2-tailed) and the *0.05 level (2-tailed).

quency of respondents falling into the three clusters was almost identical for the two samples and no significant differences were found.

Inter-Relationships between PCI Scales, Clusters, and the Abbreviated NEO-FFI Scales

Pearson product-moment correlations were used to examine interrelations between the scales of the PCI and the abbreviated scales adapted from the NEO-FFI. These correlations are presented in **Table III**. It is important to note that these correlations are based on only 147 respondents since not all of the 259 applicants completed both the PCI and the modified NEO-FFI scales. These analyses revealed a number of moderate to high correlations between the scales of these two instruments. With the exception of Competitiveness, all the scales in the PCI correlated significantly with Conscientiousness. PCI scales reflecting positive or negative interpersonal attributes (Expressivity, Negative Instrumentality, Verbal Aggressiveness, and Competitiveness) were associated with Agreeableness in the appropriate direction, while Verbal Aggressiveness was also positively correlated with Neuroticism. The PCI scales comprising the Positive Instrumental/Expressive cluster were positively correlated with the Big Five trait of Conscientiousness and, with the exception of Expressivity, with Extraversion.

As a second step toward understanding the relationships between the PCI and the abbreviated NEO-FFI scales, comparisons were made between applicants classified in the different clusters. One-way ANOVA with Tukey's test for post hoc multiple comparisons were used. The Positive Instrumental/Expressive cluster scored significantly higher than the other two on Conscientiousness ($F(2,142) = 11.44, p < 0.001$). All three groups were significantly different on Agreeableness ($F(2,142) = 44.00, p < 0.001$), with the Positive Instrumental/Expressive cluster scoring highest, and the Negative Instrumental cluster scoring lowest. The Low Motivation cluster scored in between the other two on Agreeableness, and also scored significantly higher on Neuroticism ($F(2,143) = 3.4, p < 0.035$) than the Positive Instrumental/Expressive cluster.

Scale Comparisons

For comparisons on raw scale scores, men and women were analyzed separately. Many of the traits

assessed in this study have known gender differences, and separating male and female respondents into separate groups reduces variability due solely to gender. This allows more subtle differences to be identified when comparing group means on scale scores.

An independent samples *t*-test was used to examine differences between successful (12 female, 51 male) and unsuccessful (34 female, 162 male) astronaut applicants. No differences were found when comparing these two groups on any of the 11 scales of the PCI, nor on any of the scales of the modified NEO-FFI. This is true for both the aggregate sample and when compared for men and women separately. **Table IV** shows the means and standard deviations for these two groups for the personality scales of both the PCI and the modified Big Five.

Gender Differences

Independent samples *t*-tests were also used to examine differences between female ($n = 46$) and male ($n = 213$) applicants on all scales assessed in this study. Men scored significantly higher than women on Competitiveness (12.65 vs. 10.26, $t = -4.56, p = 0.000$). Women also scored lower than men on Negative Instrumentality (8.28 vs. 9.74, $t = -2.018, p = 0.045$) and higher than men on Expressivity (23.80 vs. 22.63, $t = 2.062, p = 0.040$) and Achievement Strivings (19.12 vs. 17.86, $t = 2.590, p = 0.010$), though these findings are less significant and would be discounted after Bonferroni corrections are applied.

Separate gender comparisons were also conducted for selected and unselected applicants. Competitiveness again was the only significantly different measure, with men scoring higher than women in both groups (selected: 12.5 vs. 9.1, $t = -3.395, p = 0.001$; unselected: 12.7 vs. 10.7, $t = -3.297, p = 0.001$).

Gender was also examined in the distribution of individuals within the three clusters identified above. While the results suggest no differences between the selected and unselected applicants, both groups appear to have lower percentages of women in the Negative Instrumental cluster and higher percentages of women in the remaining two clusters. This finding is most likely due to the lower scores among female respondents on Competitiveness—a key trait characterizing the Negative Instrumental cluster. The low number of

TABLE IV. MEANS AND SD ON PERSONALITY SCALES FOR SUCCESSFUL AND UNSUCCESSFUL FINAL STAGE ASTRONAUT APPLICANTS AS WELL AS NORMATIVE (STUDENT) VALUES.

	Gender	Successful Applicant (N=63)		Unsuccessful Applicant (N=196)		Normative Values* (N=343)	
		Mean	SD	Mean	SD	Mean	SD
PCI Scales							
Instrumentality	Male	26.9	2.7	26.5	3.4	21.4	4.8
	Female	26.8	2.3	26.2	2.4	20.4	4.5
Expressivity	Male	22.6	3.0	22.6	3.8	23.0	4.0
	Female	23.8	3.2	23.8	2.8	24.7	4.1
Negative Instrumentality	Male	9.5	4.7	9.8	4.6	13.3	4.5
	Female	8.6	3.6	8.2	3.5	11.3	4.6
Verbal Aggressiveness	Male	3.7	2.4	3.5	2.3	5.4	2.9
	Female	3.3	2.0	3.5	2.3	6.4	2.9
Mastery	Male	23.1	3.7	22.8	3.6	18.9	4.8
	Female	23.1	4.0	23.0	4.1	18.5	4.8
Work Orientation	Male	22.7	1.6	22.6	1.8	19.0	3.7
	Female	23.3	1.0	23.0	1.1	20.3	3.2
Competitiveness	Male	12.5	3.0	12.7	3.2	14.5	4.0
	Female	9.1	3.8	10.7	3.6	13.4	3.8
Achievement Striving	Male	17.9	3.1	17.9	3.0	13.8	4.4
	Female	20.1	2.5	18.8	2.8	14.3	3.8
NEO-FFI Scales							
Neuroticism	Male	4.5	2.9	4.7	3.6	14.2	5.8
	Female	6.0	2.2	4.9	3.2	15.1	5.9
Extraversion	Male	24.2	3.2	24.5	3.2	21.0	4.6
	Female	26.3	3.4	23.9	3.1	22.8	4.7
Openness to Experience	Male	19.2	4.0	20.5	3.7	19.6	4.8
	Female	20.6	2.8	21.9	3.7	18.0	4.9
Agreeableness	Male	25.8	2.9	25.6	2.8	20.2	4.2
	Female	27.3	2.1	26.5	3.4	22.4	4.1
Conscientiousness	Male	27.4	2.9	27.1	3.3	19.32	5.6
	Female	28.1	3.9	27.4	2.8	21.7	5.0

*Normative values obtained from undergraduate research volunteers (N = 173 female, 170 male).

subjects available at this level of analysis makes this finding less reliable than other results discussed above.

DISCUSSION

Several key findings are suggested by the results presented above. Analysis of scores on the PCI for both the successful and unsuccessful applicant samples suggest three distinct subgroups, or clusters, in this population. The characteristics of each subgroup appear to be consistent with those identified in commercial pilots (7) and subsequently identified in Norwegian military cadets (29). These three clusters have previously been termed: Positive Instrumental/Expressive, Negative Instrumental, and Low Motivational, or alternatively, "Right Stuff," "Wrong Stuff," and "No Stuff" (7). Furthermore, these groupings have been found to correlate with performance in a number of previous studies (3,7,27). We cannot conclude that cluster membership predicts performance in these astronaut applicants since such validating analyses have yet to be conducted using these data. Previous research with active astronauts, however, has suggested that cluster membership may indeed predict astronaut performance. In a study of astronaut personality and performance, McFadden and colleagues (17) found that astronauts with higher levels of both Instrumentality and Expressivity tended to outperform their peers on both Group Living and Job Competence measures, though the reliability of those findings was limited by sample size.

One purpose of this study was the investigation of the relationship between the scales of the PCI and the

abbreviated scales of the NEO-FFI. Investigations into personality and performance in aviation, polar, and simulation studies have often used one of these personality batteries, though seldom both, and our intent was to explore the extent of commonality between the two instruments. A number of moderate but significant correlations indicate some degree of overlap between the attributes assessed by these two batteries. Furthermore, the pattern of overlap seems to support the construct validities of many of the scales. The modest correlations between certain scales of the PCI (many of which are drawn from scales designed to assess positive and negative aspects of masculinity and femininity) and those of the abbreviated NEO-FFI scales suggest that the PCI may indeed assess attributes beyond those assessed by the NEO-FFI. The PCI may, therefore, add to the description of personality over and above the NEO-FFI in both research and applied settings. Among the most interesting findings to emerge from our analyses is that membership in the Positive Instrumental/Expressive cluster (Right Stuff) was related to higher scores on Conscientiousness. Based on meta-analyses, Conscientiousness has been linked to work performance in a variety of employment settings (18,32,37). This suggests that higher levels of Conscientiousness may be a key factor that accounts for the superior performance of the Right Stuff cluster in previous research using the PCI. By contrast, higher levels of Neuroticism appear to be more characteristic of the Low Motivation (No Stuff) cluster.

Another purpose of this study was to investigate

whether personality traits, as assessed by the PCI and modified NEO-FFI scales used in this study, predicted final stage selection in the astronaut application process. To our knowledge, personality trait assessments did not play a major role in final stage astronaut selection during the period in which these data were collected (30). Our analyses showed no discernable differences in psychological testing between those applicants who were eventually selected and those who were not. Specifically, there were no significant differences on any of the raw scale scores of the traits assessed by the PCI, and none of the Big Five traits that were measured by the modified scales of the NEO-FFI. In addition, there were no differences in the distribution of applicants among the three clusters (Right Stuff, Wrong Stuff and No Stuff) when comparing successful and unsuccessful applicants. While these results suggest that there were no significant personality differences between those who were selected from those who were not, there are several factors to consider. First, it is important to acknowledge that these individuals were already highly selected based on their qualifications and accomplishments following their initial application to the program. These data suggest a certain degree of uniformity among these individuals, and the lack of discernable differences between the selected and non-selected applicants may be due in part to this homogeneity. It is also important to point out that some unidentified aspect of personality not assessed by the instruments used in this study may have had a role in final selection.

It has been claimed that astronauts are not as highly screened on interpersonal attributes as they are on instrumental traits. Findings from our analyses do not provide consistent support for this assumption. Comparison between astronaut applicants and a normative student sample did indeed indicate that students scored lower than astronaut applicants on scales reflecting achievement-oriented attributes, such as Instrumentality, Mastery, Work, and Achievement Striving as assessed by the PCI, and Conscientiousness as assessed by the NEO-FFI. However, in terms of interpersonal traits, students scored higher on scales reflecting negative attributes, including Negative Instrumentality, Verbal Aggressiveness, and Competitiveness. The attributes of arrogance and hostility associated with Negative Instrumentality and the destructiveness of an overly competitive orientation could clearly impede effective team functioning (12). Astronaut applicants also scored noticeably higher than students on Extraversion and Agreeableness using the abbreviated scales of the NEO-FFI. It is significant, however, to note that the applicant population does not differ from the student population on Expressivity—a key trait of the Positive Instrumental/Expressive cluster that has been shown to characterize superior performing individuals in previous research. Possible confounds in these findings include the fact that the applicants were tested during a period of competitive selection, and while participants were reassured that these results would not influence selection decisions, it is likely that some effects due to a response desirability bias are present in these data. In addition, a generally positive emotional environment associated with this week of astronaut selection at JSC

may account for inflated scale scores through what has been termed the “honeymoon” effect (13). Such an analysis is beyond the scope of the present study, but these possible effects warrant further investigation. Future studies should consider including social desirability scales to estimate the impact of these factors.

The analysis of gender failed to demonstrate major differences between men and women in this sample on the scales of the PCI and the modified NEO-FFI, with the sole exception of Competitiveness. Typically, men score higher than women on this measure in the general population, so such a finding is not surprising. Differences in scores on the scales of Negative Instrumentality, Expressivity, and Achievement Strivings were small and only marginally significant. The fact that male and female applicants did not differ greatly in this population is significant, however. The sexes typically differ on many of the scales on the PCI since a number of those scales have their origins in studies of gender differences in personality (34). The similarity between male and female astronaut applicants on measures of Instrumentality and Expressivity replicates previous findings in populations characterized by high achievement and career success (9,34). The different distribution of men and women among the three clusters discussed above is intriguing. The modest number of subjects in this study, particularly of women, suggests caution with regards to this finding. The lower percentage of women in the Negative Instrumental cluster would seem to be a result of the lower scores on Competitiveness in that gender, and gender differences on this measure are normal. However, this result raises the possibility that the cluster structure originally identified by Gregorich et al. (7) and subsequently linked to performance (3) is not completely consistent across genders. It is not possible to speculate on the performance implications of such a difference, and it is beyond the scope of this paper to define the most appropriate measures by which to validate the predictive utility of these traits and trait clusters. To date, the absence of formal criteria for assessing astronaut performance and the limited research opportunities have made it difficult to evaluate the predictive utility of personality measures. While research has produced promising results, the use of personality batteries for “select in” purposes requires validation of those batteries against in-flight measures of performance, including mission-specific performance parameters and those based on systematic task analyses. From the perspective of future research, the application of non-validated “select in” criteria during selection may serve to unnecessarily reduce the variability of the subject pool prior to validation studies that may justify the use of those very criteria.

The occupation of being an astronaut is both unique and multifaceted. For future studies, the inclusion of both subjective and objective performance measures as integral elements of mission operations would probably provide the most valuable indices of astronaut performance. Astronauts have been, and are, subjected to intense screening, and those who participated in our study were selected from enormous applicant pools with a rejection rate of over 97%. Taken together, the results from

this study suggest that the astronaut corps tends to attract or select individuals with high motivation and relatively low levels of negative interpersonal attributes. While all applicants had been screened for psychopathology, the correlations between measures used for “selecting out” and the personality measures applied in this study need to be further determined. Still our data suggest that, at the time of the data collection, astronauts were not as highly screened on positive expressive traits as they were on instrumental traits. Future research will need to address the performance implications of the identified trait clusters in this population. Furthermore, gender and its role in cluster membership should also be addressed in such investigations.

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