The Self-Description Inventory+, Part 1: Factor Structure and Convergent Validity Analyses

M. Kathryn Bleckley
Civil Aerospace Medical Institute
Federal Aviation Administration
Oklahoma City, OK 73125

July 2013

Final Report

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents thereof.

_____

This publication and all Office of Aerospace Medicine technical reports are available in full-text from the Civil Aerospace Medical Institute's publications Web site: www.faa.gov/go/oamtechreports

1. Report No. DOT/FAA/AM-13/13	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle The Self-Description Inventory +, Part 1: Factor Structure and Convergent Validity Analyses		5. Report Date July 2013
		6. Performing Organization Code
7. Author(s) Bleckley MK		8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aerospace Medical Institute P.O. Box 25082 Oklahoma City, OK 73125		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency name and Address Office of Aerospace Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591		13. Type of Report and Period Covered
		14. Sponsoring Agency Code

15. Supplemental Notes

This work was performed under Task AM-BRHH523

16. Abstract

Each year the FAA hires approximately 900 new air traffic controller candidates, the majority of whom take the Air Traffic Selection and Training test battery, better known as AT-SAT. This test, developed in 1997, is based on a job/task analysis conducted by Nickels, Bobko, Blair, Sands, & Tartak (1995). The test was developed as separate modules with eight subtest modules included in the current version. One module, the Experience Questionnaire (EQ), measures 12 scales of personality.

The current report examines the possibility of replacing the EQ with a Five Factor Model (FFM) measure of personality, the Self-Description Inventory + (SDI+). We examine the factor structure of the SDI+ and its convergent validity with the Goldberg Adjective Checklist.

Our results show that the SDI + has scales that are intercorrelated in a manner consistent with the FFM (Experiment 1), a factor structure consistent with its design (Experiment 2), and high levels of convergent validity with the Goldberg adjective checklist (Experiment 3). Because it has met the criteria showing it to be an FFM instrument, we will conduct concurrent validity research to determine if the SDI+ has greater predictive utility than the EQ.

17. Key Words ATCS Selection, Personality, Five Factor Models, Confirmatory Factor Analysis	18. Distribution Statement Document is available to the public through the Internet: www.faa.gov/go/oamtechreports

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 18	22. Price

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

CONTENTS

THE SELF-DESCRIPTION INVENTORY +, PART I:
FACTOR STRUCTURE AND CONVERGENT VALIDITY ANALYSES

In this paper we examine the factor structure and convergent validity of the Self-Description Inventory (SDI +) as a prerequisite to its potential use as part of the selection process for air traffic control specialists (ATCSs). Research shows that measures of personality have predictive validity in selection across many occupations (Ones, Dilchert, Viswesvaran, & Judge, 2007). The Federal Aviation Administration (FAA) currently uses a personality measure, the Experience Questionnaire (EQ), as part of the Air Traffic Selection and Training (AT-SAT) test battery. The EQ has poor psychometric properties and therefore we hypothesize that the SDI+ may have greater predictive utility.

This paper will include an introductory section that describes the activities performed by ATCSs and the history of selection testing for ATCSs. This section will be followed by a description of the AT-SAT, the test currently used to select ATCSs. While most of the AT-SAT battery consists of cognitive tests, the EQ was designed to assess applicant personality. After the EQ is described, the SDI+ test will be discussed. This will be followed by reporting of three experiments conducted to investigate the utility of the SDI+ as a replacement for the EQ.

INTRODUCTION

The ATCS occupation is the single largest and most publicly visible workforce in the FAA. ATCSs, or controllers, are responsible for the safe, efficient, and orderly flow of air traffic in the National Airspace System (NAS). Currently, about 15,000 controllers work at more than 300 air traffic control facilities and handle thousands of flights each day, from take-off to landing. Many controllers work in the glass-walled cab of the airport traffic control tower (ATCT, or tower) at airports, directing aircraft from gates, along taxiways, and while either landing or taking off from runways of both large and small airports. Relying on visual observation and radar, the tower controllers closely monitor each plane to ensure a safe distance between all aircraft, guide pilots on the ground during takeoff and landing, and ensure they arrive at their gates. Thousands of controllers also work in the less publicly visible Terminal Radar Approach Control (TRACON) and Air Route Traffic Control Center (ARTCC; also called en route or center) facilities. Here, in semi-darkened rooms, controllers use radar displays to track aircraft movements into, out of, and between airports. The TRACON controllers organize and monitor the streams of aircraft into and out of the airspace around an airport (typically, within about 50 miles of the airport). En route controllers use radar to ensure that a safe distance is maintained between aircraft as they fly towards their destinations. They also provide weather advisory and traffic information to aircraft under their control. As flights near their destinations, en route controllers transition the aircraft downwards to the terminal environment, where TRACON and then tower cab controllers guide the aircraft to a safe landing and to the gate.

The critical and important job duties and worker requirements needed to safely conduct air traffic in the NAS were identified through a formal job analysis (Nickels, Bobko, Blair, Sands, & Tartak, 1995). Examples of these requirements include dimensions of cognitive ability and personality such as: numeric ability, thinking ahead, sustained attention, problem solving, working cooperatively, decisiveness, and composure. For a full list of worker requirements used in the development of the AT-SAT battery, see Ramos, Heil, and Manning, 2001a.

Similar to what has been found for other technical tasks (Schmidt & Hunter, 1998, 2004), Nickels, et al. found that cognitive abilities were strongly associated with task performance. In fact, over the past century, selection research had focused extensive efforts on the measurement of General Intelligence ("g") or cognitive abilities. Beginning with Binet in France, continuing through the Army Alpha and Beta tests used in WWI, to modern college entrance exams (e.g., SAT, beginning in 1920), and even today, the focus continues to be on "g" with good reason. Cognitive ability ("g") is a very good predictor of job performance, especially in complex jobs (Schmidt & Hunter, 1998, 2004). The ability of "g" to predict job performance increases as job complexity increases (Gottfredson, 1997; Hunter, 1981). Cognitive ability has predictive utility in work settings because it mostly involves the ability to manage cognitive complexity (Gottfredson, 1997). Both job complexity and cognitive complexity are hallmarks of the ATC profession.

From 1981 through 2001, the FAA tested the Knowledge, Skills, Abilities, and Other Attributes (KSAOs) of ATCS appli-cants using an Office of Personnel Management (OPM) test. This test comprised three subtests: an Occupational Knowledge test, the Multiplex Controller Aptitude test, and an Analogies test. It is important to note that these three subtests are cognitive tests and that no assessment of personality[1] was made during the initial selection process. The OPM test, combined with an additional FAA Academy screening process, constituted the aptitude portion of the selection process for air traffic control candidates. Because of aggressive test preparation courses and the length of time the test was in use, the OPM test became diluted and the FAA sought to develop an alternative testing procedure. Additionally, there was hope that an improved se-lection instrument would result in shorter training times and decreased failure rates.

---

[1] Before a formal offer letter was issued, candidates submitted to psychological and security screening, as they do today.

The AT-SAT

As stated earlier, the FAA currently uses a computerized aptitude test battery known as the Air Traffic Selection and Training (AT-SAT) test battery as part of the selection process. Former U.S. military and civilian controllers, already having demonstrated their ability to control traffic, are not required to take this test. The ATCS occupational qualifications standards established by OPM require that candidates without prior air traffic control experience achieve a qualifying score on an aptitude test.

Accordingly, in 2002, the AT-SAT replaced the written aptitude test and Academy screening, described above. AT-SAT was developed to assess the abilities and other personal characteristics required to perform the critical and/or important job duties of an air traffic controller based on the job analysis conducted by Nickels et al. (1995), described previously. Seventeen candidate tests were developed and/or evaluated for use in the final version of the AT-SAT battery in the formal concurrent validation study (Ramos et al., 2001a, b). Of these, eight were selected for use: *Dials*, *Applied Math*, *Scan*, *Angles*, *Letter Factory*, *Air Traffic Scenarios Test*, *Analogies*, and the *Experience Questionnaire* (Ramos et al., 2001a). These eight tests are described in more detail elsewhere (see Ramos, et al., 2001a, 2001b).

A weighted composite score for the AT-SAT battery is computed for each applicant on a zero to 100 scale. Applicants scoring less than 70 are ineligible for hire and must wait at least one year before re-applying and re-taking AT-SAT. Applicants with scores of 70 or greater are grouped into two categories. Those scoring at least 70 but less than 85 are classified as "Qualified," while applicants with scores of 85 or higher are classified as "Well Qualified." Applicants are referred to the next stage of the selection process in categorized lists, "Well Qualified" and "Qualified."

Personality Testing in AT-SAT. The *Experience Questionnaire* (EQ) is the only AT-SAT test intended to measure personality characteristics required to perform the job of the air traffic controller. The EQ is a self-report personality instrument. It has 138 questions that assess the candidate's self-reported ability to work on a team, concentrate despite distractions, make decisions under time pressure, and other personal characteristics.

While the EQ had a significant relationship with the outcome measures in the concurrent validation study and was not significantly correlated with the aptitude tests, suggesting that it accounted for unique variance, it has some disadvantages. The foremost of these is poor psychometric properties. A test with poor psychometrics may not be measuring what it was designed to measure or may not be accurate in that measurement, even if it does have acceptable criterion-related validity. The psychometric properties of the EQ have been called into question by previous research (Manning & Heil, 2001; King, Retzlaf, Detweiler, Schroeder, & Broach, 2003). Manning and Heil conducted an oblique principal components analysis on data collected during the ATSAT concurrent validation study. The principal components analysis resulted in the extraction of only two factors, not 12, which would mirror the 12 scales that

the EQ was designed to have (Houston & Schneider, 1997, as cited in Manning & Heil, 2001, p. 60). Additionally, Manning and Heil found that the expected correlations with 16PF factors (Cattell & Mead, 2008), another measure of personality,[2] were weak and confused, indicating that the EQ does not measure personality in a typical manor. These two problems suggest that the EQ does not perform as designed. Because of this and the number of transparent, or easily faked, items in the EQ, we suggest that it is prudent to examine whether another personality instrument would perform better as part of the selection process.

The current report describes a study to assess a test that could be used by the FAA to measure personality in a more robust manner. The SDI+ measures the Five Factor Model (FFM; McCrae & Costa, 1987) of personality traits: Openness to Experience (**O**), Conscientiousness (**C**), Extraversion (**E**), Agreeableness (**A**), and Neuroticism (**N**). The opposite of neurotic behavior is emotionally stable or calm behavior. This scale is sometimes referred to in its positive valence as Emotional Stability.

Hogan (1987) has noted that the five-factor model gives personality psychology a replicable phenomenon. However, as Hogan and others have noted, the five factors do not exhaust the description of personality, they merely represent the highest hierarchical level of trait description. As McCrae, Costa, and Busch (1986) noted, measurement of the five factors gives a complete characterization of the person only at a global level. For those interested in practical applications of personality, these factors may provide sufficient descriptive detail, or it may be necessary to examine personality at a more detailed level.

Studies show that these traits are useful in predicting applicants who will be successful in various occupations such as professionals (e.g. lawyers), police, managers, sales, and skilled/semi-skilled workers (Barrick & Mount, 1991). Barrick and Mount also found that the FFM was predictive of training and job proficiency.

In addition to measuring the FFM, the SDI+ provides measures of Service Orientation (**S**) and Teamwork Orientation (**T**). Service Orientation (**S**) assesses an applicant's potential for organizational commitment. Hence, the assessment focuses on measuring predispositions for recognizing that organizational goals sometimes supplant an individual's desire for personal benefit. At times, people may be required to put their own interests aside for the good of the organization. People differ in their capacity to do this from totally the egocentric to those very willing to invest whatever is required by the organization, with little thought for the personal consequences that might ensue. People high in **S** are typically more inclined toward self-sacrifice if the good of the organization is at stake or if self-subordination is perceived as a way to achieve organizational goals.

Teamwork Orientation (**T**) assesses predispositions for working comfortably in groups versus preferences for working alone. These items focus on the applicant's preferences and capacity for working in groups to achieve organizational goals. This contrasts with predispositions for working without input

---

[2] The 16PF was used as the psychological screening instrument prior to 2007, when it was replaced by the MMPI-2.

or interference from others. High **T** respondents are comfortable in groups, able to lead as well as follow, and capable of focusing on team goals. Also, they are willing to compromise on specific methods of achieving overall goals when group cohesion requires it. People low on **T** are uncomfortable working closely with others, impatient with others, and prefer to rely on themselves rather than others.

The inclusion of S and T, along with the measurement of a more widely accepted model of personality (i.e., the FFM), make the SDI+ an appealing potential replacement for the EQ in the ATCS selection process. However, before we can replace the EQ with the SDI+, the Uniform Guidelines on Employee Selection Procedures (Equal Employment Opportunity Commission, 1978) recommended that we demonstrate the validity of an instrument before we use it as part of a merit selection process. Therefore, evidence needs to be gathered showing that the SDI+ measures the Five Factor Model (FFM) as it was designed to do.

Three experiments were conducted to the test factor structure and convergent validity of the SDI+. To preview our findings, the SDI+ met all the criteria against which we tested it. In Experiment 1, we report descriptive statistics from a sub-sample of ATCS trainees. In Experiment 2, we report the results of a confirmatory factor analysis (CFA) using both the U.S. Air Force scoring matrix (see Christal, 1994) and a simple structure model based on that scoring matrix. In Experiment 3, we report convergent validity analyses using the Goldberg Adjective Checklist (Goldberg, 1992) as our measure of the FFM.

Experiment 1. Preliminary Descriptive Analyses

Before collecting sufficient data to conduct CFA and convergent validity analyses, we examined the properties of the SDI+ in a sub-sample of 480 ATCS trainees. It seemed prudent to ensure that the SDI+ had no fatal flaws before investing the time and resources necessary to conduct CFA and convergent validity analyses. Fatal flaws include distributions and correlations that are different from those seen in other FFM scales in the ATCS population.

The SDI+ was administered to 496 ATCS trainees at the FAA Academy that participated in research during 2008 and 2009. The 220 SDI+ statements were presented via a computer program with a 5-point Likert-type answer scale (see Figure 1). The responses to negatively-valenced questions were reversed, and factor scores were derived based on the U. S. Air Force scoring matrix, which relates each item to its appropriate factor (Christal, 1994). Because there are different numbers of questions for each of the factors, ranging from 21 to 40, T-scores were computed to equate the factor scores. Bivariate correlations among the factors were computed as well.

Of the 496 participants, 16 did not complete the questionnaire, and their incomplete data were excluded from the analyses. The descriptive statistics for each of the seven factors and the Kolmogorov-Smirnov (K-S) test of normality are seen in Table 1. The K-S indicated the scores for openness to experience (O), conscientiousness (C), extroversion (E), agreeableness (A), neuroticism (N), and service orientation (S) were significantly non-normal and that only teamwork (T) was normally
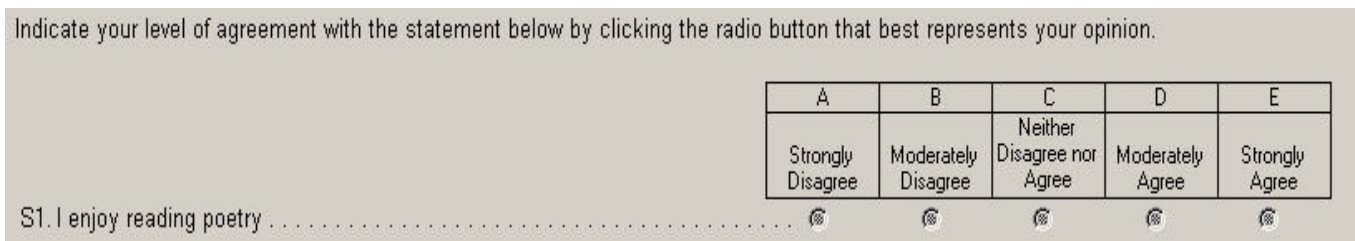
Figure 1. An example of the item presentation format for the SDI+.

Table 1. Descriptive Statistics for the SDI+ scales in a small sample of 480 ATCS trainees.

	Descriptive Statistics				Kolmogorov-Smirnov[a]		
	Mean	Std Error	Maximum	Minimum	Statistic	df	Sig.
Openness to Experience	50	.45644	79.29	19.40	.042	480	.042
Conscientiousness	50	.45644	69.47	18.20	.056	480	.001
Extroversion	50	.45644	68.92	18.12	.062	480	.000
Agreeableness	50	.45644	66.32	18.96	.075	480	.000
Neuroticism	50	.45644	82.52	36.27	.095	480	.000
Teamwork Orientation	50	.45644	74.68	25.03	.032	480	.200*
Service Orientation	50	.45644	73.55	20.83	.066	480	.000

a. Lilliefors Significance Correction

* This is a lower bound of the true significance.

distributed. The K-S test also indicated that conscientiousness (C), agreeableness (A), and neuroticism (N) were significantly non-normal. The correlation matrix (see Table 2) shows that most of the correlations were significant at p=.01.

The pattern of correlations is consistent with other measures of FFM, and the relationship of **S** and **T** with each other and the other factors is consistent with expectations. Examination of the correlation matrix reveals a typically strongly positive relationship between **A** and **E**, as well as the strongly negative relationships between **N** and each of the following factors: **C**, **E**, and **A** (see Goldberg, 1992; Barrick & Mount, 1991). The strong, positive relationships between **T** and the traditional factors of **C**, **E**, and **A** are likely due, in part, to shared items, as well as the effects of **C**, **E**, and **A** on cooperation in teams. **S** does not share items with any other factors but has strong correlations with **C** and **A**, likely due to **C** and **A's** impact on subordinating one's goals for the greater good. Analyses examining the viability of **T** without the shared items resulted will be reported in Experiment 2.

Table 2. Bivariate correlations among the factor scores (N= 480).

	O	C	E	A	N	S	T
Openness to Experience	--						
Conscientiousness	.078	--					
Extroversion	.007	**.392**	--				
Agreeableness	.064	**.643**	**.527**	--			
Neuroticism	**.123**	**-.567**	**-.565**	**-.667**	--		
Service	**-.160**	**.427**	**.224**	**.587**	**-.586**	--	
Teamwork	.078	**.666**	**.777**	**.785**	**-.662**	**.480**	--

Correlations in **bold** are significant at the .01 level.

Examination of histograms for **C**, **A**, and **N** suggests that the non-normality may be due to skewness (see Figures 2-8). For **C** and **A**, the distributions were negatively skewed, with most ATCS trainees scoring higher than the mean on these traits. **N** was positively skewed, indicating low levels of neuroticism in this sample. These deviations from normality are in accord with other data from this population.

These analyses suggest that SDI+ scores have relationships that are similar to other measures of the FFM. We concluded that the SDI+ is sufficiently sound to invest additional resources needed to conduct confirmatory factor analyses (CFA).

Experiment 2. Confirmatory Factor Analyses

CFA tests the hypothesis that the way that the participants responded to the items resulted in relationships among the items that were predicted by the SDI+ developers. More specifically, we hypothesize that the items designed to be strongly related are strongly related to each other and are not strongly related to other families of items (Anderson & Gerbing, 1998). For example, in a successful CFA, we would expect to find items loading on their intended factors with values greater than |.3| and high levels of model fit as measured by fit indices such as the Root Mean Squared Error of Approximation (RMSEA; desired values < 0.08) and the Comparative Fit Index (CFI; desired values >0.95).

The CFA analyses were conducted using both the original scoring matrix and a simple structure model (SSM). A SSM imposes the constraint that no item may load on more than one factor (i.e. be related to more than one family). The simple structure model provides a more rigorous test of the factor structure of the instrument, and will allow more rigorous testing of the convergent validity of the SDI+ (Experiment 3).
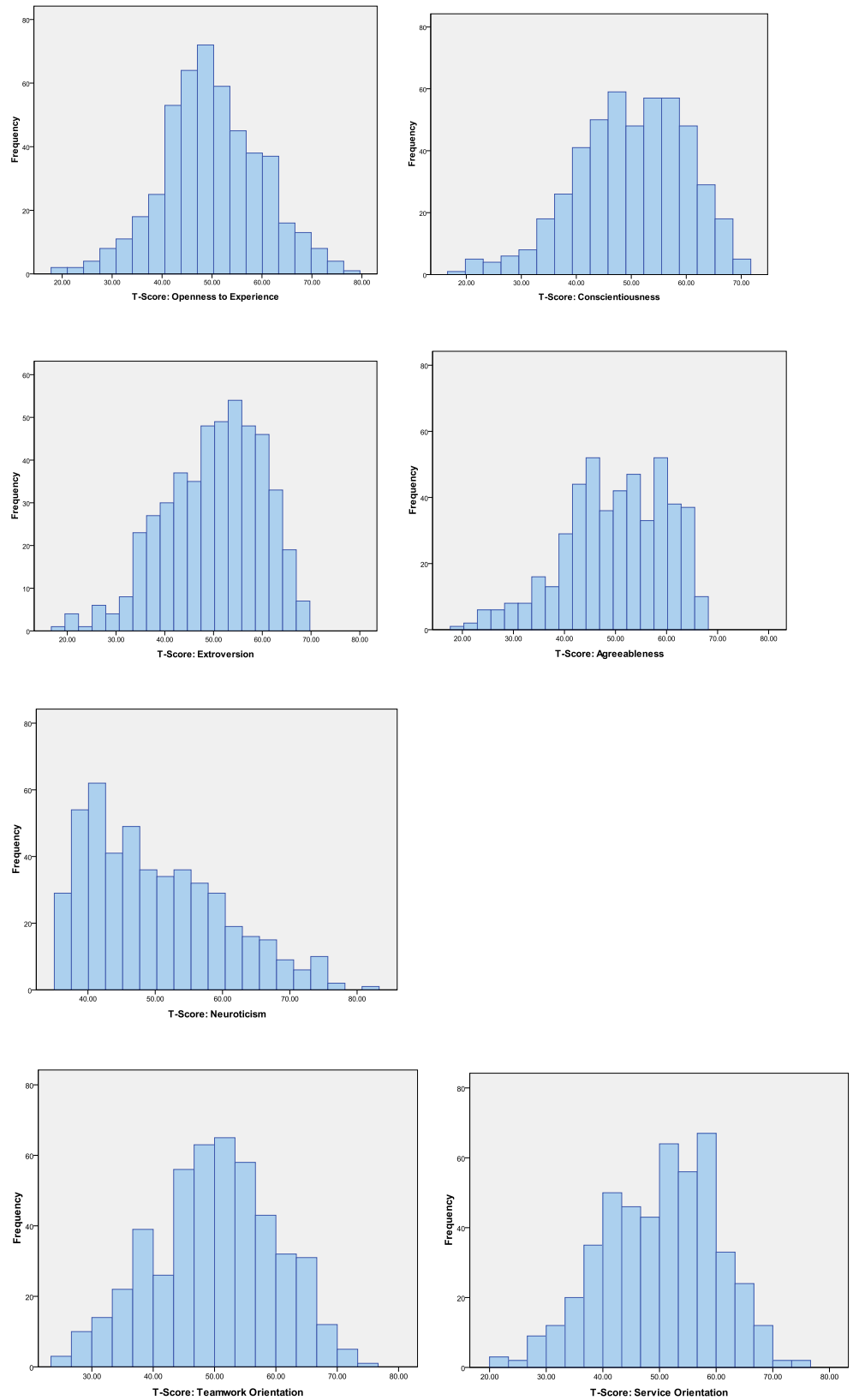
Figures 2-8. Histograms of T-Scores for the Seven Factors of SDI+.

METHOD

The SDI+ was administered to 867 ATCS trainees who attended the FAA Academy from 2008-2009. Of these, 838 completed the questionnaire. This sample included the 480 participants from the subsample analyzed previously. The participants were presented with a 5-point Likert-type answer scale for each of the 220 statements. Data were then submitted to a CFA using LISREL 8.54 (Jöreskog & Sörbom, 2003). The factor structure for the CFA was based on the USAF scoring matrix. We constrained the model such that each statement could only be related to its intended factor(s). For example, an item intended to measure agreeableness (**A**) would not be allowed to have any relationship to neuroticism (**N**). For the model based on the original scoring matrix, some statements were allowed to have relationships to more than one factor, such as agreeableness (**A**) and teamwork (**T**). For the SSM, each item was allowed relationship to *only* its primary factor.

RESULTS

While the CFA using the original scoring matrix was acceptable (χ^2 (23834) = 63931.935, p<.0001; CFI = .961; RMSEA = .0611), an SSM is preferred as it provides a more rigorous test. The SSM was also a good fit to the data (χ^2 (23849) = 64113.196, p<.0001; CFI = .961; RMSEA = .0612)**,** but 17 of the questions had factor loadings <|.3|. Factor loadings between -.3 and +.3 mean that the items are not sufficiently related to their factor. Eliminating these questions produced a better fitting SSM model (χ^2 (23849) = 64113.196, p<.0001; CFI = .964; RMSEA = .0599). The correlation matrix for SSM can be seen in Table 3. The full factor loading matrix can be seen in Appendix A.

DISCUSSION

The analyses suggest that SDI+ factor structure is consistent with the theory upon which it is based. That is, seven well-defined factors comprise the items as designed. The fit of the model to the data was good, as demonstrated by the RMSEA (<0.08) and the CFI (>0.95). That is, the relationships between the items and their intended factors are strong.

The negative correlations between **N** and three FFM factors, **C**, **E**, and **A,** are consistent with relationships observed in previous research in a sample of ATCS trainees (unpublished analyses of NEO data from Schroeder, Broach, & Young, 1993), as shown in Table 4. The non-significant correlations between **O** and **E** and between **O** and **N** in our data are similar to the small correlations obtained in the Schroeder et al. data.

These results show that the SDI+ has a factor structure consistent with the theory on which the measure is based. Additionally, the factor correlations are similar to those observed in a known FFM instrument administered to ATCSs. Therefore, further investigation into the convergent validity of SDI+ is warranted.

Experiment 3. Convergent Validity Analyses

Thus far, we have shown that the relationships between the items and their factors are consistent with a seven-factor model. When a new instrument is developed, it is also important to determine if it measures what it was designed to measure. In this case, we need to determine if the SDI+ measures the FFM as intended. To do this we will test its convergent validity with a known measure of the FFM.

As shown in Experiment 2, the CFA on the SDI+ had 5 factors +2, which is consistent with a FFM. However, we also need to show that the SDI+'s five factors are *empirically* the same as those measured by a known FFM instrument. This requires collecting data from individuals who have taken both the SDI + and a known FFM instrument, in this case, the Goldberg Adjective Checklist (GAC). We will then analyze whether the first five factors in the SDI+ (**OCEAN**) measure the same thing as the **OCEAN** factors in the GAC. The **S** and **T** factors are unique to the SDI+ and, therefore, cannot be tested using this method. They remain in the model to ensure that their presence will not distort the FFM factors as measured by the SDI+.

Table 3. Factor Correlations for Simple Structure Model (203 items).

	O	C	E	A	N	S	T
O	--						
C	0.159	--					
E	0.041*	0.450	--				
A	0.205	0.695	0.543	--			
N	-0.013*	-0.638	-0.588	-0.647	--		
S	0.008*	0.576	0.352	0.694	-0.726	--	
T	0.176	0.748	0.760	0.841	-0.728	0.683	--

*not significantly different from zero

Table 4. Factor correlations from Schroeder et al. (1993).

Schroeder et al. (1993) ATCS NEO N= 1817					
	O	C	E	A	N
O	--				
C	.049*	--			
E	.364**	.363**	--		
A	.220**	.291**	.291**	--	
N	-.080**	-.485**	-.383**	-.372**	--

*significant <0.05
**significant <.001

There are three levels of convergent validity analyses (CVA): Parallel Forms, Tau-Equivalence, and Congeneric Equivalence (Jöreskog, 1971). Every test score (s) is composed of two parts, the true score (t) and error variance (e). Therefore, $s = t + e$. The three types of tests of convergent validity examine how similar each part of this equation is across different instruments.

In our case, Parallel Forms is not an appropriate method for analyzing CVA. Parallel Forms is typically used to test the convergent validity of alternate versions of the same test. Because the tests we are using have neither a common item structure nor a common response format, they cannot reach the level of convergent validity represented by Parallel Forms. For Tau-Equivalence, the true scores of the two tests must be equal, but the error terms are allowed to vary. For Congeneric Equivalence, or common origin equivalence, we expect the true scores to be similar but not equal. We will test first tau-equivalence and then, if its criterion is not met, we will test congeneric equivalence.

METHOD

The SDI+ and GAC were administered to 1,552 ATCS trainees who attended the FAA Academy from 2008-2011. The data from Experiment 2 are included in this sample. Of these, 1339 completed both questionnaires. The 220 items of the SDI+ were presented with a 5-point Likert-type answer scale (see Figure 1); the 100 adjectives of the GAC were presented with a 9-point Likert-type answer scale (Figure 9). The 17 items identified in the previous analyses as not having a significant relationship with their factor were excluded. Factor analyses using LISREL 8.54 (Jöreskog & Sörbom, 2003) were conducted to determine the level of convergent validity of the SDI+ with the GAC. The SDI+ was tested for tau-equivalence (true scores equal) with GAC. The functional test for tau-equivalence involves constraining the factor correlations for the corresponding factors to equal 1. If the model with this constraint fits the data well, then the true scores must be equal because they are perfectly correlated (i.e., $r^2 = 1$).

1	2	3	4	5	6	7	8	9
Extremely Inaccurate	Very Inaccurate	Quite Inaccurate	Slightly Inaccurate	Neither	Slightly Accurate	Quite Accurate	Very Accurate	Extremely Accurate
1. Active............								
2. Agreeable..........								

Figure 9. An example of the item presentation format for the GAC.

RESULTS

The criteria for tau-equivalence were met (χ^2 (50658) = 152042.063, p<.0001; CFI = .955; RMSEA = .0568). Both the Comparative Fit Index and the Root Mean Square Error of Approximation were within acceptable levels. Because Tau-Equivalence, a more rigorous test of convergent validity, was met, we did not need to test Congeneric Equivalence. Table 5 presents the factor correlation matrix. Note that the correlations of corresponding factors from the two scales were constrained to equal 1. This allows us to conclude that the Self Description Inventory + (SDI+) and Goldberg Adjective Checklist (GAC) measure the same FFM constructs. We included the factors **S** and **T** to ensure that their inclusion did not distort the relationships among the FFM factors.

DISCUSSION

These analyses support the contention that the SDI+ is a measure of the FFM of personality. The meeting of tau-equivalence between the SDI+ and GAC was better than expected given the different item and response formats of the two tests. It is clear from this that the FFM portion of the SDI+ works as intended.

The additional factors of service orientation and teamwork orientation may provide additional predictive validity beyond that provided by other FFM measures. Although these new factors have high correlations with some of the original five, the new items, and therefore their new factors, may provide additional information that is predictive of success as an ATCS. Controllers need to work cooperatively in teams, and a measure of a person's willingness to do so may prove to be useful in selecting future ATCSs who can successfully function in the increasingly collaborative environment of the future Next Generation Air Transportation System. The service orientation factor is less obviously useful, but there are times when all employees, including ATCSs, need to subjugate their aspirations or needs for the good of the organization.

The next stage of validation will involve concurrent validation with incumbent controllers. In a concurrent validation study, job incumbents are scored on the predictor measures and some measure(s) of work performance. The SDI+ and EQ will both be administered to Tower ATCSs, along with two measures of job performance. Analyses will be conducted to determine which measure of personality is a better predictor of job performance. The results of the concurrent validation will be provided to the FAA's human resources management to contribute to a decision about whether to replace the EQ with the SDI+.

Table 5. Factor correlations among the 7 SDI+ factors and the 5 GAC factors.

	O_{SDI+}	C_{SDI+}	E_{SDI+}	A_{SDI+}	N_{SDI+}	S_{SDI+}	T_{SDI+}	O_{GAC}	C_{GAC}	E_{GAC}	A_{GAC}	N_{GAC}
O_{SDI+}	1.000											
C_{SDI+}	-0.297	1.000										
E_{SDI+}	0.172	-0.268	1.000									
A_{SDI+}	-0.395	0.560	-0.343	1.000								
N_{SDI+}	-0.155	0.492	-0.431	0.497	1.000							
S_{SDI+}	0.155	0.419	0.189	0.569	-0.557	1.000						
T_{SDI+}	0.322	0.554	0.678	0.724	-0.618	0.503	1.000					
O_{GAC}	**1.000**	-0.343	0.254	-0.462	-0.244	0.210	0.396	1.000				
C_{GAC}	-0.289	**1.000**	-0.277	0.555	0.533	0.446	0.550	-0.380	1.000			
E_{GAC}	0.200	-0.277	**1.000**	-0.337	-0.406	0.175	0.658	0.307	-0.318	1.000		
A_{GAC}	-0.389	0.563	-0.342	**1.000**	0.512	0.585	0.722	-0.506	0.617	-0.363	1.000	
N_{GAC}	-0.180	0.500	-0.420	0.512	**1.000**	-0.546	-0.611	-0.275	0.590	-0.444	0.562	1.000

Bolded correlations indicate the factor correlations constrained to equal 1.0 as the test for tau-equivalence

REFERENCES

Anderson, J.C., & Gerbing, D.W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*, 411-423.

Barrick, M.R., & Mount, M.K. (1991). The big five personality dimensions and job performance: A meta-analysis. *Personnel Psychology, 44,* 1-26.

Cattell, H.E.P., & Mead, A.D. (2008). The sixteen personality factor questionnaire (16PF). In G. Boyle, G. Matthews, & D.H. Saklofske, (Eds.). *The SAGE handbook of personality theory and assessment; Vol. 2 Personality measurement and testing* (pp. 135-178). Los Angeles, CA: Sage.

Christal, R.E. (1994). R&D summary report on contract F33615-91-D-0010. Unpublished final status report for Delivery Order 0010 for the period Feb 93 to Nov 94. Brooks AFB, TX: Manpower and Personnel Division, U.S. Air Force Human Resources Laboratory.

Equal Employment Opportunity Commission. (1978). Uniform guidelines on employee selection procedures, 29 CFR 1607.

Goldberg, L.R. (1992). The development of markers for the Big-Five factor structure. *Psychological Assessment*, *4*, 26-42.

Gottfredson, L.S. (1997). Why g matters: The complexity of everyday life. *Intelligence, 24*(1), 79-132.

Hogan, R. (1987). Personality psychology: Back to basics. In J. Aronoff, A.I. Rabin, & R.A. Zucker (Eds.). *The emergence of personality* (pp. 79-104). New York: Springer.

Hunter, J.E. (1981). The economic benefits of personnel selection using ability tests: A state of the art review including a detailed analysis of the dollar benefit of U.S. Employment Service placements and a critique of the low cutoff method of test use. Report prepared for the U.S. Employment Service, U.S. Department of Labor, Washington, DC, January 15, 1981.

Jöreskog, K.G. (1971). Statistical analysis of sets of congeneric tests, *Psychometrika, 36,* 109-133.

Jöreskog, K.G., & Sörbom, D. (2003). LISREL 8.54 for Windows [Computer software]. Lincolnwood, IL: Scientific Software International, Inc.

King, R.E., Retzlaff, P.D., Detwiler, C.A., Schroeder, D.J., & Broach, D. (2003). *Use of personality assessment measures in the selection of air traffic control specialists* (Report No. DOT/FAA/AM-03/20). Washington, DC: FAA Office of Aerospace Medicine.

Manning, C.A., & Heil, M.C. (2001). The relationship of FAA archival data to AT-SAT predictor and criterion measures. In *Ramos, R.A., Heil, M.C., and Manning, C.A. (Eds.). Documentation of validity for the AT-SAT computerized test battery, Volume II. (*Report No. DOT/FAA/AM-01/6)*,* 49-60. Washington, DC: FAA Office of Aviation Medicine.

McCrae, R.R., & Costa, P.T. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology, 52,* 81-90.

McCrae, R.R., Costa, P.T., Jr., & Busch, C.M. (1986). Evaluating comprehensiveness in personality systems: The California Q-Set and the five-factor model. *Journal of Personality, 54,* 430-446.

Nickels, B.J., Bobko, P., Blair, M.D., Sands, W.A., & Tartak, E.L. (1995). Separation and control assessment (SACHA) final job analysis report. Bethesda, MD: University Research Corporation.

Ones, D.S., Dilchert, S., Viswesvaran, C., & Judge, T.A. (2007). In support of personality assessment in organizational settings. *Personnel Psychology, 60,* 995-1027.

Ramos, R.A., Heil, M.C., and Manning, C.A. (2001a). *Documentation of validity for the AT-SAT computerized test battery, Volume I.* (Report No. DOT/FAA/AM-01/5). Washington, DC: FAA Office of Aviation Medicine.

Ramos, R.A., Heil, M.C., and Manning, C.A. (2001b). *Documentation of validity for the AT-SAT computerized test battery, Volume II.* (Report No. DOT/FAA/AM-01/6). Washington, DC: FAA Office of Aviation Medicine.

Schmidt F.L., & Hunter, J.E. (1998). The validity and utility of selection methods in personnel psychology: practical and theoretical implications of 85 years of research findings, *Psychological Bulletin, 124*, 262-274.

Schmidt F.L., & Hunter, J.E. (2004). General mental ability in the world of work: occupational attainment and job performance. *Journal of Personality and Social Psychology, 86*, 162-173.

Schroeder, D.J., Broach, D., & Young, W.C. (1993). *Contributions of personality to the prediction of success in initial air traffic control specialist training* (Report No. DOT/FAA/AM-93/4). Washington, DC: FAA Office of Aviation Medicine.

Confirmatory Factor Analysis for SDI+ Simple Structure Model
Completely Standardized Solution Factor Loadings

O	C	E	A	N	S	T
– –	0.406	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	– –	0.164
– –	0.324	– –	– –	– –	– –	– –
– –	– –	0.236	– –	– –	– –	– –
– –	– –	– –	– –	– –	– –	0.523
– –	– –	– –	– –	– –	– –	-0.395
– –	– –	– –	– –	– –	0.286	– –
– –	0.443	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	– –	-0.392
– –	-0.433	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	0.412	– –
– –	– –	– –	0.458	– –	– –	– –
– –	0.516	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	0.415	– –
– –	– –	– –	– –	0.356	– –	– –
– –	– –	0.189	– –	– –	– –	– –
– –	0.302	– –	– –	– –	– –	– –
– –	– –	– –	0.481	– –	– –	– –
– –	– –	– –	– –	– –	0.437	– –
– –	– –	– –	– –	– –	– –	0.276
– –	– –	– –	0.635	– –	– –	– –
– –	– –	– –	– –	0.432	– –	– –
– –	– –	– –	– –	– –	0.416	– –
– –	– –	– –	– –	– –	– –	0.188
0.337	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	– –	0.329
– –	0.482	– –	– –	– –	– –	– –
0.404	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.454	– –	– –
– –	-0.504	– –	– –	– –	– –	– –
– –	– –	– –	0.650	– –	– –	– –
– –	– –	– –	0.697	– –	– –	– –
– –	– –	– –	0.613	– –	– –	– –
– –	– –	0.473	– –	– –	– –	– –
– –	0.595	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	0.419	– –
– –	– –	– –	– –	– –	– –	0.414
– –	– –	– –	– –	– –	0.588	– –
– –	– –	– –	– –	0.549	– –	– –
– –	– –	– –	0.641	– –	– –	– –
0.352	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.497	– –	– –
– –	– –	– –	– –	– –	0.372	– –
0.424	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.624	– –	– –

0.552	- -	- -	- -	- -	- -	- -
-0.471	- -	- -	- -	- -	- -	- -
- -	- -	- -	0.555	- -	- -	- -
0.457	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	-0.161
0.529	- -	- -	- -	- -	- -	- -
0.527	- -	- -	- -	- -	- -	- -
- -	- -	-0.658	- -	- -	- -	- -
- -	- -	0.537	- -	- -	- -	- -
- -	- -	- -	- -	0.605	- -	- -
- -	- -	- -	- -	0.543	- -	- -
- -	- -	- -	0.522	- -	- -	- -
- -	- -	0.489	- -	- -	- -	- -
- -	0.584	- -	- -	- -	- -	- -
- -	- -	- -	0.731	- -	- -	- -
- -	- -	- -	- -	- -	- -	-0.287
- -	- -	- -	- -	- -	- -	0.429
- -	- -	-0.556	- -	- -	- -	- -
- -	- -	-0.543	- -	- -	- -	- -
- -	- -	- -	0.617	- -	- -	- -
0.564	- -	- -	- -	- -	- -	- -
- -	- -	0.374	- -	- -	- -	- -
- -	- -	- -	- -	- -	- -	-0.639
- -	- -	-0.738	- -	- -	- -	- -
- -	- -	-0.643	- -	- -	- -	- -
- -	- -	- -	- -	0.513	- -	- -
- -	- -	- -	- -	- -	- -	0.574
- -	0.450	- -	- -	- -	- -	- -
- -	0.567	- -	- -	- -	- -	- -
- -	- -	- -	0.654	- -	- -	- -
- -	- -	- -	- -	0.473	- -	- -
- -	- -	- -	- -	0.523	- -	- -
- -	- -	- -	0.673	- -	- -	- -
- -	0.606	- -	- -	- -	- -	- -
- -	0.695	- -	- -	- -	- -	- -
- -	- -	- -	- -	0.514	- -	- -
- -	- -	- -	0.766	- -	- -	- -
- -	- -	- -	- -	- -	- -	-0.246
- -	- -	- -	- -	0.611	- -	- -
- -	- -	- -	0.576	- -	- -	- -
- -	- -	- -	- -	- -	- -	-0.543
0.301	- -	- -	- -	- -	- -	- -
0.426	- -	- -	- -	- -	- -	- -
- -	- -	-0.630	- -	- -	- -	- -
- -	0.659	- -	- -	- -	- -	- -
0.569	- -	- -	- -	- -	- -	- -
0.659	- -	- -	- -	- -	- -	- -
- -	- -	- -	- -	- -	0.390	- -
- -	- -	0.568	- -	- -	- -	- -
- -	- -	- -	- -	-0.358	- -	- -
- -	0.574	- -	- -	- -	- -	- -
- -	- -	- -	0.698	- -	- -	- -

– –	– –	– –	– –	– –	0.603	– –
– –	– –	– –	0.611	– –	– –	– –
– –	– –	– –	– –	0.656	– –	– –
– –	– –	– –	– –	0.450	– –	– –
– –	– –	– –	– –	0.502	– –	– –
0.471	– –	– –	– –	– –	– –	– –
– –	– –	– –	0.485	– –	– –	– –
– –	– –	– –	– –	0.668	– –	– –
0.602	– –	– –	– –	– –	– –	– –
– –	0.633	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	– –	−0.697
– –	– –	0.606	– –	– –	– –	– –
– –	– –	– –	−0.597	– –	– –	– –
– –	– –	– –	0.467	– –	– –	– –
0.466	– –	– –	– –	– –	– –	– –
– –	– –	0.423	– –	– –	– –	– –
– –	0.480	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.653	– –	– –
– –	– –	– –	– –	0.665	– –	– –
– –	– –	– –	– –	0.714	– –	– –
– –	– –	0.682	– –	– –	– –	– –
– –	– –	0.500	– –	– –	– –	– –
0.536	– –	– –	– –	– –	– –	– –
0.404	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.768	– –	– –
– –	– –	– –	– –	0.669	– –	– –
– –	– –	– –	– –	– –	0.460	– –
– –	0.644	– –	– –	– –	– –	– –
– –	0.530	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.770	– –	– –
– –	– –	−0.726	– –	– –	– –	– –
– –	– –	0.291	– –	– –	– –	– –
– –	– –	– –	– –	0.681	– –	– –
– –	– –	– –	0.690	– –	– –	– –
0.401	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	0.684	– –
– –	– –	– –	– –	0.600	– –	– –
– –	– –	0.494	– –	– –	– –	– –
– –	– –	– –	– –	0.614	– –	– –
– –	0.621	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.759	– –	– –
– –	– –	– –	– –	– –	0.641	– –
– –	– –	−0.822	– –	– –	– –	– –
– –	– –	– –	0.727	– –	– –	– –
– –	– –	0.691	– –	– –	– –	– –
– –	– –	– –	−0.406	– –	– –	– –
– –	– –	−0.720	– –	– –	– –	– –
– –	– –	– –	−0.581	– –	– –	– –
– –	– –	– –	– –	– –	– –	−0.483
– –	– –	– –	0.692	– –	– –	– –
– –	– –	– –	– –	0.736	– –	– –
– –	– –	−0.814	– –	– –	– –	– –

– –	0.659	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.608	– –	– –
– –	– –	– –	– –	– –	– –	-0.388
– –	– –	-0.781	– –	– –	– –	– –
– –	– –	– –	0.729	– –	– –	– –
– –	0.485	– –	– –	– –	– –	– –
– –	– –	0.752	– –	– –	– –	– –
– –	– –	– –	– –	– –	0.258	– –
– –	-0.652	– –	– –	– –	– –	– –
– –	– –	-0.809	– –	– –	– –	– –
– –	– –	-0.814	– –	– –	– –	– –
– –	– –	– –	-0.462	– –	– –	– –
– –	– –	– –	– –	– –	0.520	– –
– –	– –	– –	– –	0.716	– –	– –
– –	0.536	– –	– –	– –	– –	– –
– –	– –	-0.845	– –	– –	– –	– –
– –	– –	-0.794	– –	– –	– –	– –
– –	0.559	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	0.489	– –
– –	– –	– –	– –	– –	– –	-0.439
– –	0.752	– –	– –	– –	– –	– –
– –	– –	– –	0.763	– –	– –	– –
0.539	– –	– –	– –	– –	– –	– –
– –	0.686	– –	– –	– –	– –	– –
– –	0.735	– –	– –	– –	– –	– –
– –	0.676	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.778	– –	– –
– –	0.118	– –	– –	– –	– –	– –
– –	– –	– –	– –	0.676	– –	– –
0.378	– –	– –	– –	– –	– –	– –
– –	– –	– –	0.793	– –	– –	– –
– –	– –	– –	– –	0.616	– –	– –
– –	– –	– –	-0.558	– –	– –	– –
– –	– –	– –	– –	0.761	– –	– –
– –	– –	– –	– –	– –	– –	0.580
0.479	– –	– –	– –	– –	– –	– –
0.483	– –	– –	– –	– –	– –	– –
0.547	– –	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	0.108	– –
– –	– –	– –	– –	– –	– –	-0.707
– –	– –	– –	0.712	– –	– –	– –
– –	– –	– –	0.684	– –	– –	– –
– –	– –	– –	0.770	– –	– –	– –
– –	– –	– –	– –	– –	0.607	– –
– –	– –	– –	– –	0.689	– –	– –
– –	– –	– –	– –	0.677	– –	– –
– –	– –	– –	0.478	– –	– –	– –
– –	– –	– –	– –	– –	0.616	– –
– –	– –	– –	– –	– –	– –	-0.058
– –	0.736	– –	– –	– –	– –	– –
– –	-0.662	– –	– –	– –	– –	– –
– –	0.611	– –	– –	– –	– –	– –

A4

– –	– –	– –	– –	– –	– –	-0.688
– –	– –	– –	– –	0.611	– –	– –
0.635	– –	– –	– –	– –	– –	– –
0.452	– –	– –	A –	– –	– –	– –
– –	– –	– –	– –	– –	0.537	– –
– –	0.550	– –	– –	– –	– –	– –
– –	0.205	– –	– –	– –	– –	– –
– –	– –	– –	– –	– –	– –	0.495
– –	– –	– –	0.748	– –	– –	– –
– –	– –	– –	– –	– –	– –	0.375
0.267	– –	– –	– –	– –	– –	– –
– –	– –	– –	-0.435	– –	– –	– –
– –	– –	– –	0.556	– –	– –	– –
– –	0.412	– –	– –	– –	– –	– –
0.306	– –	– –	– –	– –	– –	– –
– –	– –	-0.769	– –	– –	– –	– –
– –	– –	0.461	– –	– –	– –	– –
– –	– –	– –	– –	– –	-0.003	– –
– –	– –	– –	0.523	– –	– –	– –