What Explains Personality Covariation? A Test of the Socioecological Complexity Hypothesis

Abstract

Correlations among distinct aspects of behavior are foundational to personality science, but the field remains far from a consensus regarding the causes of such covariation. We advance a novel explanation for personality covariation, which views trait covariance as being shaped within a particular socioecology. We hypothesize that the degree of personality covariation observed within a society will be inversely related to the society's socioecological complexity, i.e. its diversity of social and occupational niches. Using personality survey data from participant samples in 55 nations (N = 17,637), we demonstrate that the Big Five dimensions are more strongly inter-correlated in less complex societies, where complexity is indexed by nation-level measures of economic development, urbanization, and sectoral diversity. This inverse relationship is robust to controls accounting for a number of methodological and response biases. Our findings support the socioecological complexity hypothesis, and more generally bolster functionalist accounts of trait covariation.

Keywords: behavioral syndromes; Big Five Inventory (BFI); General Factor of Personality (GFP); socioecological complexity; trait covariation

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One of personality psychology's primary achievements has been the factor-analytic derivation of models of personality trait structure, which distill inter-correlated behavioral descriptors down to broader dimensions (Digman, 1997; John et al., 2008; Lee & Ashton, 2004; McCrae & Costa, 2008; Musek, 2007; Saucier et al., 2013). Despite the centrality of inter-correlated behaviors to personality science, the field remains far from a consensus regarding the causes of such covariation (Cramer et al., 2012; Wood et al., 2015). Amid this ambiguity, we highlight a central question: What determines the extent to which distinct aspects of personality covary within individuals, and manifest as a certain number of independent personality dimensions at the population level (e.g. one, two, five)?

A popular explanation for trait covariation is that distinct aspects of personality are correlated because they are caused by the same latent psychological variable (Boorsboom et al., 2003; Cattell, 1950). For example, if sociable and assertive behaviors are correlated, this would be explained by the fact that both classes of behavior are caused by a unitary latent variable called "extraversion," which is one of the "Big Five" personality traits (McCrae & Costa, 2008). Likewise, correlations among the Big Five dimensions form the basis for either one (Musek, 2007) or two (Digman, 2007) highest-order personality dimensions, which ostensibly arise from corresponding latent variables that regulate nearly every aspect of human behavior. However, this latent variable approach has been heavily criticized for its circularity; specifically, that latent variables are first inferred from, and then invoked to explain, observed patterns of behavioral covariation (Ashton et al., 2009; Boorsboom et al., 2003; Cramer et al., 2012; Wood et al., 2015).

Recently, functionalist theories have been proposed to explain the causes of personality covariation in humans (Cramer et al., 2012; Figueredo et al., 2011; Gurven et al., 2013; Lukaszewski, 2013; Nettle, 2011; Wood et al., 2015) and other animals (Laskowski, Montiglio, & Pruitt, 2016; Sih et al., 2015; Wolf & Krause, 2014). These biologically informed perspectives share several key features. First, they posit that manifest behaviors will be inter-correlated to the extent that they tend to be influenced by the same functional motivations; for example, status pursuit, resource accrual, self-protection, or investment in offspring. Second, they acknowledge that behaviors may be elicited in different ways as a function of socioecological contingencies in the attainment of functional objectives. For example, imagine that, in Society A, obtaining high status usually requires both social networking and organizational skill. Given this incentive structure, variation across individuals in status motivation would be expected to produce a positive correlation between extraverted and conscientious behaviors. Within Society B, on the other hand, high status can be obtained *either* through investment in social networking *or* organizational skill *or* other specializations – in which case elevated status motivation would elicit extraverted or conscientious behaviors (or neither) selectively across individuals, leaving these dimensions more weakly correlated.

These considerations imply that patterns of personality covariation may vary across populations encountering different socioecological conditions. Consistent with this, accumulating evidence suggests that the degree and structure of trait covariation differs across societies (Gurven et al., 2013; Saucier et al., 2014). Particularly striking is recent evidence that ‘distinct’ traits may tend to covary more strongly in small-scale subsistence societies than in post-industrial societies (Bailey et al., 2013; Gurven et al., 2013).

This paper advances a novel hypothesis regarding the origins of cross-cultural differences in personality covariation: that distinct aspects of personality will be more weakly inter-correlated within more complex societies containing a larger number of diverse specialized social and occupational niches. The total set of personality profiles is thus expected to increase with socioecological complexity.

The Socioecological Complexity Hypothesis

Humans are zoologically unusual in the extent to which we are adapted for large scale collective action (Kaplan et al., 2009; Powers et al., 2016). Cooperation in stable groups not only unlocks potential benefits that could not be produced by individuals acting alone, but also permits group members to benefit from the efficiencies of labor divisions, with individuals enhancing productivity by specializing in particular social or occupational niches (Jaeggi, Hooper, Beheim, Kaplan, & Gurven, 2016; Mises, 1949; Tooby et al., 2006). In small-scale subsistence societies, such as those in which humans evolved, niche specialization occurs within extended kin-based “households” where men, women, and children focus on different, complementary tasks such as gathering, hunting, childcare, tool-making, and cooking (Gurven et al., 2009; Stieglitz et al., 2013). At the community level, there is less specialization though certain individuals may take a larger role in leadership, group defense, conflict arbitration, storytelling, healing, or aspects of food production (Kelly, 1995; Sugiyama & Scalise-Sugiyama, 2003; von Rueden et al., 2014). Through specialization, individuals are able to exchange services, resulting in net cooperative benefits (Jaeggi et al., 2016).

Although niche specialization is pronounced within small-scale human societies relative to other primate species, it is limited relative to that observed in post-industrial societies. Indeed, the story of modern history is characterized by increasing *socioecological complexity* – i.e. niche specialization within large-scale cooperative groups and institutions. This process was spurred by the Neolithic agricultural revolution ~12,000 years ago, which enabled larger, denser, more stratified and sedentary populations (Powers & Lehmann 2014). Technological innovation and occupational diversity expanded with these demographic changes (Bonner, 2004; Carneiro, 1967; Kaplan et al., 2009). For example, among indigenous North Americans, the number of leadership functions (e.g. military, religious, judicial, productive) increased with a society's maximal community size (Feinman & Neitzel, 1984). Socioecological complexity accelerated further with the industrial and technological revolutions of the past two centuries and the expansion of markets in a monetized economy (Ridley, 2010). Whereas our foraging ancestors had to be "jacks of all trades" while specializing to some degree based on differential aptitude (Kelly, 1995; Sugiyama & Scalise-Sugiyama, 2003), residents of post-industrial societies specialize in highly particular roles and rely upon specialists from other households, communities, and nations to provide complementary goods and services. Urbanization further concentrates large numbers of individuals in competitive labor, mating and social markets (Henrich et al., 2005), which increases the local density of distinct niches and thereby the incentive to specialize one's phenotype in novel ways (Jeanson et al., 2007; Mises, 1949). Larger populations with specialization often benefit from greater economic efficiency through "economies of scale", whereby high volume reduces average production costs, and through "economies of scope", whereby payoffs increase from the diversification of goods and services (Panzar & Willig 1981).

We propose that the degree of personality covariation observed within a society will be inversely related to its socioecological complexity. Our logic relies on the premise that the number of social and occupational niches available within a society correlates positively with the specificity of those niches and, therefore, the extent to which phenotypic specialization is an optimal strategy for pursuing one's interests. If so, it follows that the number of personality profiles – i.e. specialized combinations of behavioral attributes – that manifest within a society will correspond with the diversity and specificity of available niches.

Citizens of complex post-industrial societies can pursue their interests through a broad array of specialized niches – such that an individual can produce resources, seek status, and care for offspring in various ways that are compatible with a correspondingly diverse set of specialized personality profiles. For example, there may be specialized roles whose fulfillment is optimally facilitated by a combination of low extraversion, low agreeableness, and high conscientiousness (e.g., an insurance claims adjuster), and others that are most effectively fulfilled by individuals with high extraversion, agreeableness and openness, and any level of conscientiousness (e.g., a night club promoter). As individuals become specialized for these (and many other) niches within complex societies, the ontogenetic feedback loops between trait-exemplifying behaviors and successful role fulfillment (Sih et al., 2015; Wolf & Krause, 2014;

Wood et al., 2015) should lead to the development of a correspondingly diverse set of multivariate personality profiles.

Within less complex societies, on the other hand, individuals tend to face more similar socioecological contingencies presenting fewer alternatives for how – and how much – to specialize. In small-scale societies, people tend to live in small groups of related and other familiar individuals with reduced choice in social or sexual partners. Individuals of the same age and gender tend to engage in similar forms of subsistence work, offspring care, and social exchange (Gurven et al., 2009). Achieving success within the fewer available social and occupational niches may be facilitated by relatively few *combinations* of behavioral attributes (Figueredo et al., 2011; Gurven et al., 2013; von Rueden et al., 2008; 2014). For example, due to the egalitarian ethic and consensual decision-making of many small-scale societies, extraversion without agreeableness and conscientiousness can be ineffective or costly when community members gather for discussion or to socialize. The high risks of underproduction or disease favor risk aversion, and individuals who have strong social networks due to extraverted and agreeable behaviors may best manage the risks of being open to new experiences. Thus, within societies of lower complexity, the feedback loops between behaviors and successful role fulfillment may tend to produce positive correlations between multiple aspects of personality (Gurven et al., 2013).

We evaluate this hypothesis by testing one of its main predictions: that distinct aspects of personality will be more strongly inter-correlated within less complex societies. To this end, we analyze the average inter-factor correlations among the Big Five personality traits across 55 nations of varying socioecological complexity, with the latter indexed by each nation's Human Development Index, level of Urbanization, and Sectoral Diversity. Because correlations across survey items may also vary due to properties of subject samples that are not relevant to our hypothesis, we also include multiple pertinent controls in our cross-national analysis: sample size, literacy indicators, and multiple survey response biases. Although we were agnostic regarding which inter-factor correlations would associate most strongly with cross-national variation in socioecological complexity, we also conducted exploratory analyses in parallel to reveal these specific patterns for future theoretical development.

Methods

Participants

Participants were 17,637 men (N = 7,347) and women (N = 10,290), predominantly college students, from 55 nations. They participated in a standardized data collection as part of the International Sexuality Description Project (ISDP; Schmitt et al., 2007). The ISDP contains participant samples from countries in all major world regions, including North and South America; Northern, Southern, and Eastern Europe; the Middle East; Africa; South, Southeast, and East Asia; and Australia and Oceania. Online supplemental materials (*S1*) report nation-level demographic and other summary information for these ISDP participant samples.

Measures

Personality Covariation (The Big Five)

Personality was assessed by the Big Five Inventory (BFI; Benet-Martinez & John, 1998), a 44-item, self-report instrument that measures each of the big five dimensions: Agreeableness (A), Conscientiousness (C), Emotional Stability (ES), Extraversion (E), and Openness to Experience (O) (John et al., 2008). Across nations, the BFI was administered in 29 different languages; 45 of the 55 participant samples completed the surveys in their primary native language, whereas 10 bilingual samples completed surveys in a secondary language. Scores for each of the BFI scales were computed by Schmitt et al. (2007), and these scores were employed in the current analyses. Each nation's degree of personality covariation was computed as the mean pair-wise correlation among the BFI scales, in the metric of r^2. We first squared each of the ten individual pair-wise correlations, before taking an average of the r^2 values for each nation. (Note: results were extremely similar when using r and r^2 values, respectively, as the metric of trait covariation. We viewed r^2 as a superior metric because it covaries linearly with the conceptual variable of interest: the extent to which different scales share variance.)

Consistent with prior research on higher-order factors of personality (McCrae et al., 2008; van der Linden et al., 2010), correlations among the BFI scales were overwhelmingly positive. Out of 550 inter-factor correlations (10 inter-factor correlations x 55 nations), none were statistically significant negative associations. Thus, it made little difference whether we took the direction of correlations into account in computing mean inter-factor r or r^2 values.

Socioecological Complexity

There is no single metric that fully captures the notion of socioecological complexity at the nation level. However, we can estimate each focal nation's complexity by employing three indirect measures that should each be positively associated with socioecological complexity. Two measures supplied by the United Nations (hdr.undp.org/en) include the Human Development Index (HDI) and the level of Urbanization. For all focal nations, we took these indices from the year 2000, which was the time during which the ISDP personality data were collected. In addition, we employed a nation-level measure of Sectoral Diversity provided by Harvard University's Atlas of Economic Complexity (atlas.cid.harvard.edu).

HDI is computed based on three indicators from each nation: average levels of education, gross domestic product, and life expectancy (United Nations, hdr.undp.org/en). These indicators have been found to serve as reliable proxies for the extent to which a nation's people (i) have access to social, political and economic institutions that incentivize the acquisition of niche-specialized skills, (ii) actually possess specialized and economically productive capacities (Stewart, 2013), and (iii) benefit from economies of scale and scope (Henrich et al., 2005). Moreover, a nation's level of wealth and education are both determinants and consequences of the extent to which its citizens have discretionary time not obligatorily spent on meeting basic subsistence needs. Discretionary time is necessary for individuals to invest in cultivating phenotypic specializations, thereby making it a key ecological constraint on niche diversification (Dunbar et al., 2009).

Urbanization was also estimated for each nation based on United Nations statistics (United Nations, hdr.undp.org/en). This measure is computed as the percentage of a nation's population that lives in an urban (versus rural) setting. Urban centers are hubs of socioeconomic complexity as defined by niche specialization, with many specialists clustered in close proximity in order to efficiently exchange services (Mises, 1949). More rural areas, on the other hand, are agrarian and subsistence-based, with lower population densities and fewer distinct social and occupational niches (Mises, 1949).

Sectoral Diversity is a measure that reflects how many different types of products a nation is able to produce. It is computed based on a nation's volume of exports by Harvard University's Atlas of Economic Complexity (atlas.cid.harvard.edu). This export-based index is widely used in macroeconomics as a crude proxy for sectoral diversity, which is taken to reflect the maturity and productivity of a nation's market economy (Hausman & Hidalgo, 2014). Sectoral Diversity scores were only available for 49 of the 55 focal nations in the current study, so we used regression to impute the six missing values based on HDI and Urbanization scores.

In order to combine these nation-level indicators, we created a composite *Socioecological Complexity Index* for each nation by conducting a principal components analysis wherein HDI, Urbanization, and Sectoral Diversity were forced to load onto a single factor (which explained 82% of the total variance). Loadings onto this factor were .93 (HDI), .89 (Sectoral Diversity), and .86 (Urbanization). Standardized factor scores weighted by these loadings were computed according to the regression method.

Control Variables

Seven control variables were selected to test alternative explanations for the predicted patterns. Below, we explain how each control was operationalized.

Sample size was included in order to control for possible variation across samples in the reliability of the mean inter-factor correlations, which should be lower in smaller samples. Sample size was positively skewed, so we applied a logarithmic transformation to this variable that reduced its skewness from 5.22 to 1.28. This log-transformed sample size variable (log N) was employed for all analyses.

Literacy was controlled to test the hypothesis that trait covariation would be greater among less literate samples due to imprecise understanding of fine grained distinctions among items with similar valence or meaning. We operationalized literacy in two ways. First, we employed each nation's literacy rate as reported by the United Nations, which represents the percentage of the population that can read and write (hdr.undp.org/en). Second, we coded whether each subject sample completed the BFI in their native language (versus a secondary language). The use of this latter measure assumes that bilingual subjects are more literate in their nation's primary language than in a secondary language.

Negative item bias refers to the tendency to agree with affirmatively worded items for a given construct more than negatively worded items, which could generate artefactual correlations across different personality scales. To control for this, we took values from Schmitt and Allik

(2005), who computed negative item bias for the samples based on their scores on the Rosenberg Self-Esteem scale (Rosenberg, 1965). Thus, each sample's negative item bias reflects the tendency to agree with positively scored items (e.g., "On the whole, I am satisfied with myself") than to disagree with negatively scored items (e.g., "At times I think I am no good at all").

Acquiescence bias refers to the tendency to agree with items regardless of content (i.e., to agree with positively and negatively scored items for the same construct). Like negative item bias, cross-sample differences in acquiescence bias could produce artefactual correlations with trait covariation across nations. Acquiescence bias scores were taken from Schmitt et al.'s (2007) analysis of the current BFI data.

Evaluative bias refers to the tendency of people to rate themselves positively, that is, to be in possession of socially desirable characteristics. This was operationalized in two ways. The first evaluative bias indicator is each nation's mean score on the BFI scale measuring Agreeableness, which is the most unambiguously socially desirable of the Big Five dimensions. The second indicator is each nation's mean score on the Rosenberg Self-Esteem Scale (Rosenberg, 1965), which was taken for the current sample from Schmitt and Allik (2005). Although this scale is intended to measure genuine positive self-regard, it should also be expected to capture any evaluative biases that exist at the nation level.

Statistical Analyses

We first examined zero-order correlations among all measured variables using Pearson's *r*. We also employ Spearman's ρ to guard against the possibility that observed cross-national Pearson correlations might be inflated (or deflated) by a few outlying nations.

We next employed Generalized Estimating Equations (GEE) to determine whether the association of Socioecological Complexity with trait covariation remained when including our control variables. GEE extends the Generalized Linear Model to situations where observations are correlated (Agresti, 2013). Our cross-national sample contained data from countries spread across six continents (Africa, Asia, Australia/Oceania, Europe, North America, South America). Countries within the same continent may share historical, cultural, or geographical similarity that can produce autocorrelation in the data, so our GEE models treat continent as a random component (nations nested within continents) to account for possible non-independence across countries; this increases the validity of standard error estimation. We specified an exchangeable correlation structure, which assumes similar covariance among countries from the same continent (Agresti, 2013). An unstructured correlation structure was rejected because it produced substantially worse model fit based on quasi-likelihood information criterion (QIC), a modified form of the Akaike Information Criterion that is appropriate for GEE (Pan, 2001). All analyses were conducted using SPSS (v23).

Our systematic modeling procedure is as follows: In models 1-8, socioecological complexity, as well as each individual control variable, were entered as univariate predictors of personality covariation in sequence. In models 9-15, socioecological complexity was entered as a simultaneous predictor along with each individual control variable in sequence. Model 16 includes socioecological complexity along with all control variables as simultaneous predictors. Model 17 includes socioecological complexity and all covariates that were significant predictors in models 1-8. The final two models exclude socioecological complexity, but include all control variables simultaneously (model 18) or all control variables that were significant univariate predictors in models 1-8 (model 19). Complete results from all 19 GEE models are presented in online supplemental materials (see *S2*). To assess comparative fit across all models, we ranked models according to Akaike weights, which were calculated based on corrected QIC (Pan, 2001). Larger weights indicate better comparative model fit.

Finally, in order to determine whether the observed cross-national differences in trait covariation have implications for (i) interpretation of the current findings and (ii) cross-cultural validity of the BFI, we performed tests of factorial measurement invariance (MI) for each of the BFI factors. To this end, we planned a multi-step procedure wherein we would begin by testing for weak factorial MI, before proceeding to more stringent MI tests. For the initial tests of weak factorial MI, we employed EQS (v6.2) to run confirmatory factor analyses (CFAs) examining the fit of multi-group models for each BFI factor scale. In these tests, a given BFI scale's items loaded onto the corresponding latent factor, and item loadings were permitted to vary freely across the 55 national samples (Steencamp & Baumgartner, 1998). We evaluated model fit using (robust) fit indices: Satorra-Bentler χ^2, CFI, and RMSEA. As reported below, because none of the BFI scales exhibited any modicum of MI, proceeding to the more stringent tests (e.g., with cross-group equality constraints on item loadings) was unwarranted.

Results

Nation-level descriptive statistics for all measured variables are presented in Table 1. ISDP samples were drawn from a diverse set of nations, whose socioecological complexity as indexed by HDI, Urbanization, and Sectoral Diversity ranged from very low (e.g., Bangladesh, Ethiopia) to very high (e.g., Belgium, Japan). There was also substantial variation across nations in personality covariation, with mean inter-factor r^2 values ranging from .01 to .21 (mean r values ranged from + 0.10 to + 0.46).

Zero-order correlations supported our predictions derived from the socioecological complexity hypothesis (Table 2). HDI, Urbanization, and Sectoral Diversity all exhibited robust negative cross-national correlations with personality covariation as measured by mean inter-factor correlations. The cross-national correlation between the Socioecological Complexity Index and personality covariation was -.53 in the metric of Pearson's *r* and -.49 in the metric of Spearman's ρ (Figure 1).

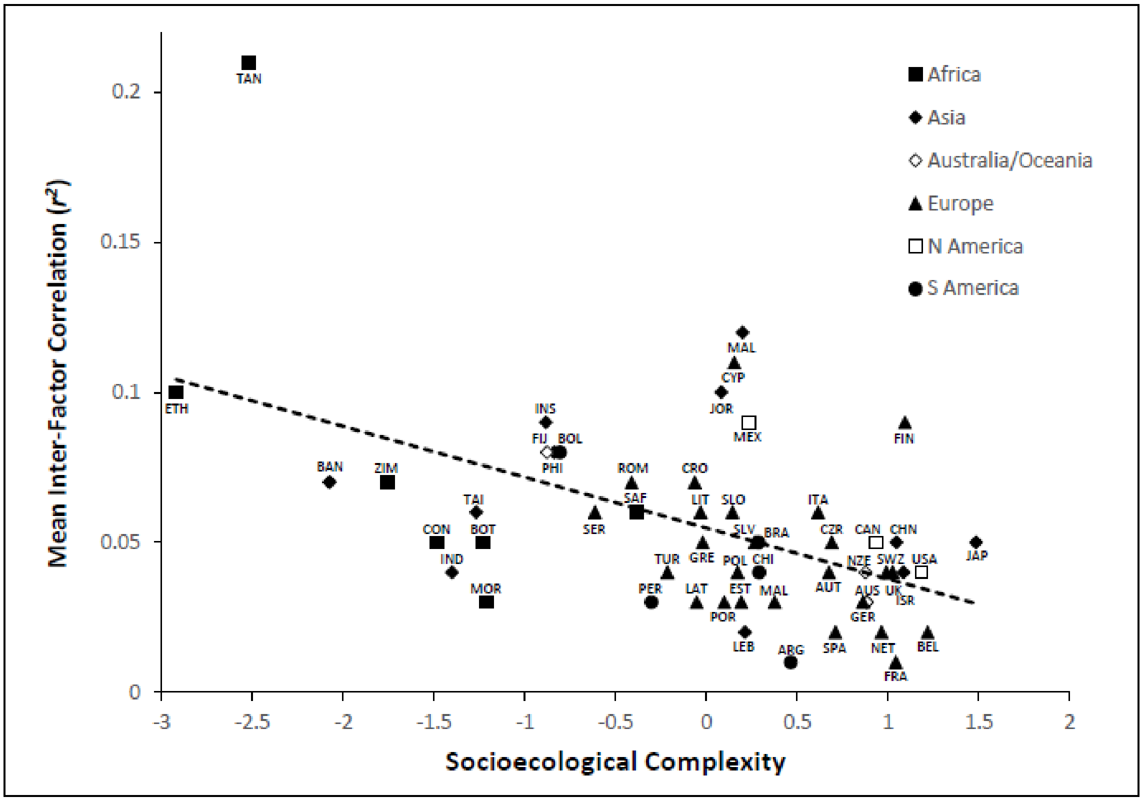

Figure 1. Scatterplot depicting the cross-national association between personality covariation (mean inter-factor correlations among the big five dimensions) and the socioecological complexity index. The key for three-letter nation codes can be found in *S1*.

However, many of the possible control variables were also correlated with the focal variables (Table 2). The Socioecological Complexity Index was correlated with sample size, negative item bias, mean agreeableness, national literacy, and BFI language. Personality covariation was also correlated with these same variables. Although several of these correlations might reflect genuine differences in personality expression in populations varying in complexity, a stronger test of the socioecological complexity hypothesis is to determine whether the association between these focal variables remains when controlling for these other confounding factors.

The GEE models unequivocally support the conclusion that socioecological complexity is the strongest unique predictor of personality covariation. Across all 19 models evaluated, socioecological complexity always exhibited a much larger effect size than any of the predictors it competed with to explain variance (*S2*), ranging from -0.376 (Model 17) to -0.692 (Model 10). Nonetheless, it was of interest to determine which combination(s) of predictor variables best accounted for differences in personality covariation across nations. Table 3 presents models 1-8 (the single-predictor models) as well as the best-fitting model. The best-fitting model (Akaike weight = .18) included only socioecological complexity and acquiescence bias as predictors, with the former exhibiting a much larger effect size (Table 3; see also *S2*). The second-ranked model (Akaike weight = .16) included only socioecological complexity and sample size as predictors, with the former again exhibiting a much larger effect size (see *S2*). The third-ranked model (Akaike weight = .12) was model 1, in which socioecological complexity was the only predictor (Table 3; see also *S2*). Note also that spatial non-independence within continents likely explained little variance in any of the models, since QICs were near equivalent to QICs when data were assumed to be independent within continents (i.e. under an independence correlation structure).

Because the predictors in these models tended to correlate, it was important to address collinearity concerns. To this end, in each GEE model, we evaluated the parameter correlation of each covariate with that for socioecological complexity (see *S2* for parameter correlations). As can be seen in *S2*, there were several models wherein parameter correlations approached or surpassed .90; the parameter estimates in these models should therefore be interpreted with caution. Fortunately, given that model fit can be high even with collinear predictors, none of the three top-ranking (i.e. best-fitting) models had parameter correlation values that warranted collinearity concerns (*S2*).

Exploratory analyses predicting specific BFI inter-factor correlations

Table 4 presents the results of exploratory analyses intended to examine which specific patterns of inter-factor correlations drove the overall association of socioecological complexity with trait covariation. At the zero-order level, complexity was significantly negatively associated with (positive) inter-factor correlations between C/A, C/O, C/ES, ES/O, and A/O (Table 4).

As described in the previous section, the best-fitting GEE model predicting mean trait-covariation controlled for acquiescence bias. We therefore computed parallel GEE models predicting each specific inter-factor correlation (Table 4; see *S3* for complete model statistics). The effects from these models upheld, and indeed strengthened, the associations evident in the zero-order correlations (Table 4).

Measurement invariance tests

To test for weak factorial MI of the BFI scales across nations, we evaluated the fit of multi-group CFAs (one for each BFI factor) across the 55 samples in the ISDP. Results demonstrated that the multi-group models fit very poorly for all scales: agreeableness [χ^2 (1485)

= 14279.42, $p < .0001$; CFI = .00; RMSEA = .212 (90% CI: .209, .214)], conscientiousness [χ^2 (1485) = 21380.37, $p < .0001$; CFI = .25; RMSEA = .206 (90% CI: .203, .208)], emotional stability [χ^2 (1100) = 22257.46, $p < .0001$; CFI = .00; RMSEA = .31 (90% CI: .306, .312)], extraversion [χ^2 (1485) = 25560.99, $p < .0001$; CFI = .25; RMSEA = .226 (90% CI: .223, .228)], and openness [χ^2 (1485) = 19942.81, $p < .0001$; CFI = .25; RMSEA = .198 (90% CI: .195, .200)]. The poor fit of these multi-group CFAs is inconsistent with weak factorial MI of the BFI across samples.

Table 1. Descriptive statistics for all measured variables

Measure	# Nations	*M*	*SD*	Range
Sample Size (log N)	55	2.39	.27	1.79 – 3.45
National Literacy (percent literate)	55	92.35%	12.39	39 – 100%
BFI Language (secondary vs. native)	55	.81	.39	0 (n = 10) or 1 (n = 45)
Negative item bias	55	1.74	.75	0 – 3.4
Acquiescence bias	55	46.5	3.58	37.8 – 52.9
Agreeableness	55	47.5	2.73	42.2 – 53.7
Rosenberg Self-esteem	55	30.5	1.51	25.5 – 33.6
HDI	55	.72	.14	.28 – .90
Urbanization (percent urban)	55	69.40%	18.60	17.5 – 100%
Sectoral Diversity	49	.54	.87	-1.15 – 2.12
Socioecological Complexity Index	55	0	1.00	-3.14 – 1.36
Mean Inter-Factor Correlation (r^2)	55	.05	.03	.01 – .21

Table 2. Cross-national correlations among all measured variables

Measures	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Sample size (log N)	--	-.31**	.00	-.01	.18	.21	.11	.37**	.29*	.36**	.38**	-.40**
2. Negative item bias	-.30*	--	.14	.21	-.22	-.35**	-.07	-.54**	-.38**	-.56**	-.54**	.45**
3. Acquiescence bias	.02	.14	--	.10	.29*	-.06	.08	.19	.06	-.35**	-.22	-.11
4. Agreeableness	-.09	.19	.07	--	.32*	-.31*	-.23	-.30*	-.30*	.31*	-.33*	.34*
5. Rosenberg Self-Esteem	.19	-.35**	.20	.29*	--	.22	.27*	.15	.12	.00	.10	-.14
6. Literacy	.21	-.45**	-.31*	-.29*	.09	--	.55**	.85**	.63**	.66**	.79**	-.34*
7. BFI Language	.08	-.16	.07	-.25	.31*	.50**	--	.47**	.26	.35**	.40**	-.14
8. HDI	.46**	-.61**	-.28*	-.23	.15	.75**	.34*	--	.76**	.84**	.96**	-.51**
9. Urbanization	.40**	-.42**	-.04	-.27*	.15	.27*	.14	.64**	--	.57**	.86**	-.52**
10. Sectoral Diversity	.33*	-.55**	-.42**	-.26	.08	.71**	.32*	.85**	.49**	--	.89**	-.41**
11. Socioecological Complexity	.44**	-.58**	-.27*	-.28*	.11	.61**	.26	.92**	.82**	.87**	--	-.53**
12. Inter-Factor Correlation (r^2)	-.47**	.54**	-.02	.32*	-.19	-.27*	-.01	-.49**	-.53**	-.35**	-.49**	--

Note. Correlations are presented in the metric of Pearson's *r* above the diagonal and Spearman's ρ beneath the diagonal. BFI = Big Five Inventory; HDI = Human Development Index. *p < .05; **p < .01.

Table 3. Selected GEE models predicting personality covariation across nations

Model #	Single-Predictor Models	Standardized Coefficient	Standard Error	Wald 95% CI	Wald χ^2	Akaike Weight (Model Fit)
1	Socioecological Complexity	-.54	.02	-.59; -.50	523.87***	.12
2	Native Language	-.11	.02	-.53; .32	.25	<.001
3	National Literacy	-.40	.03	-.46; -.34	180.95***	<.001
4	Sample Size (log N)	-.41	.10	-.61; -.21	16.15***	<.001
5	Negative Item Bias	.48	.08	.33; .64	36.56***	.01
6	Acquiescence Bias	-.13	.14	-.42; .16	.767	<.001
7	Self-Esteem	-.11	.10	-.32; .08	1.38	<.001
8	Agreeableness	.34	.06	.21; .46	26.78***	<.001
	Best-Fitting Model					
15	Socioecological Complexity	-.60	.01	-.63; -.57	1829.59***	.18
	Acquiescence Bias	-.23	.06	-.33; -.12	16.78***	

Note. This table presents only a subset of all 19 models evaluated (Models #1-8 & 15). Akaike weights are based on a comparison of all 19 models, which are presented in the supplement (*S2*) along with additional model statistics. As described in text, GEE models were computed using an exchangeable working correlation matrix. ***p < .001.

Table 4. Associations of specific inter-factor BFI correlations with Socioecological Complexity

	Association with Socioecological Complexity	
Inter-Factor Correlation	***Zero-order (r)***	***Acquiescence Bias Controlled (GEEs)***
C/A	-.54***	-.55***
C/O	-.52***	-.60***
C/ES	-.41**	-.46***
ES/O	-.40**	-.36***
A/O	-.34*	-.35***
E/O	-.23	-.24**
A/ES	-.22	-.31**
E/C	-.20	-.16
E/A	-.14	-.20
E/ES	-.04	-.08

Note. As described in text, GEEs controlled for acquiescence bias and treated continent as a random factor (see *S3* for complete model statistics). A = Agreeableness; C = Conscientiousness; E = Extraversion; ES = Emotional Stability; O = Openness. *p < .05; **p < .01; *** p < .001

Discussion

The present findings demonstrate that distinct aspects of human personality covary to a greater degree in nations with lower socioecological complexity as indexed by broad measures of human socioeconomic development, urbanization, and sectoral diversity. Specifically, the big five personality dimensions, assessed by the BFI, tended to be positively inter-correlated, and these correlations were larger on average in less complex societies characterized by relatively lower niche diversity and specialization. Thus, urban, high-income, developed countries with greater socioecological complexity exhibit a more diverse personality profile than rural, low-income countries with lower complexity. These associations were not due to geographic autocorrelation and survived multiple controls for literacy indicators, sample size, and psychometric biases – which in turn helps argue against several plausible alternative explanations for the findings.

Although the present study confirmed the existence of cross-national correlations predicted by the socioecological complexity hypothesis, it contained several limitations that should be addressed. While the association of complexity with trait covariation withstood various controls, some caution is warranted in the interpretation of these effect size estimates. Quantitative simulations suggest that controlling for potentially confounding variables is problematic when measures for covariates are unreliable or vary in reliability (Westfall & Yarkoni, 2016). The comparative reliability of the nation-level predictor variables in the current study is unknown, so this should be kept in mind when interpreting the models controlling for possible confounders. Moreover, we could have neglected to include control variables that would test other alternative explanations for the findings. It will be important for future research to bolster the internal validity of the observed correlations, and to test any alternative explanations that are put forth to explain these patterns.

Another issue pertains to the finding that none of the BFI scales were measurement-invariant across nations. This indicates that the BFI items do not assess the latent variables posited by the five factor model equivalently across samples. One possible explanation for this measurement-variance is that the BFI items were (for whatever reason) simply interpreted somewhat differently across translations or cultural contexts. Another, more substantive, explanation for the BFI's measurement-variance is that the latent structure of manifest personality actually differs across societies of variable socioecological structure and complexity. This possibility is consistent with recent research suggesting that, within low-complexity populations, the BFI items load onto fewer phenotypic dimensions than within the high-complexity societies on which the five factor model was inductively derived (Gurven et al., 2013). For example, Gurven et al. (2013) studied personality structure among Tsimane' hunter-horticulturalists and found that the BFI items clustered onto two broad phenotypic dimensions, dubbed "Prosociality" and "Industriousness", which were (i) composed of heterogeneous combinations of items from different BFI scales, (ii) strongly positively inter-correlated, and (iii) a close match with the functionally important niches within Tsimane' socioecology. The content of these Tsimane'-specific personality dimensions was distinct from other higher-order factor solutions of the Big Five that have been observed (e.g., alpha-beta; Digman, 1997). However, the very existence of personality covariance that forms the basis for higher-order factors (of variable content) is consistent with Ashton et al.'s (2009) proposal that such factors reflect the "blending" of lower-order personality indicators via cross-factor item loadings.

Manifest personality structures that vary in their number and content of dimensions across populations comports well with the logic that underpins the socioecological complexity hypothesis, but the resultant measurement-variance of the BFI might call into question the use of inter-factor correlations as our metric of personality covariation. To assuage this concern, we note that it is likely that greater mean inter-factor correlations would track cross-national differences in the overall degree of trait covariance, even if the BFI items did not tap the same latent trait dimensions across populations. Indeed, despite the aforementioned finding that Tsimane' personality exhibits a unique two-factor (rather than five-factor) structure (Gurven et al., 2013), their pattern of BFI inter-factor correlations conforms to the trend evident in our cross-national data. Within this small-scale subsistence society, which clearly has lower complexity than any population represented in the present sample, the standard BFI scales shared 29% of their variance on average (which is higher than the largest r^2 value in the current study). This bodes well for the generalizability of the socioecological complexity hypothesis, and may illustrate how greater item-level trait covariance will manifest in larger correlations among composites formed of those items, regardless of their specific configuration. Nonetheless, some caution is warranted in the interpretation of our findings given the apparent measurement-variance of the BFI across nations.

The measurement-variance of the BFI scales suggests that we should be especially circumspect when interpreting the observed associations of specific inter-factor correlations with socioecological complexity. Even so, these exploratory analyses might facilitate future theory development insofar as they shed light on which aspects of behavior tend to cluster together more strongly as complexity decreases. The factor combinations whose associations diminished most strongly with greater complexity were more likely to involve Openness (4 out of 4: O/C, O/A, O/ES, O/E) and Conscientiousness (3 out of 4: C/E, C/A and C/ES) than Emotional Stability (2 out of 4: ES/C, ES/O), Agreeableness (2 out of 4: A/C, A/O), or Extraversion (1 out of 4: E/O). These findings might help illuminate why specific factors like Openness sometimes fail to extract in emic studies (e.g. De Raad 1994). The fact that Extraversion's association with other specific factors did not covary strongly with complexity was not predicted a priori, but is potentially consistent with the idea that this dimension may fundamentally reflect variation in status motivation (Ashton et al., 2002). The pursuit of status is a universal human motive (Anderson et al., 2015), but occupancy of prestigious niches may be facilitated by different combinations of behavioral attributes that correspond to specific local imperatives of collective benefit generation (von Rueden et al., 2008). If so, perhaps some aspects of Extraversion (e.g., boldness) universally track latent status motivation, along with variable combinations of indicators from other BFI dimensions (see Gurven et al., 2013; von Rueden et al., 2015).

The current study's findings, as well as its methodological limitations, clearly suggest the need for additional research on personality structure within populations that are more representative of the full spectrum of human socioecological variation. The samples from the current study included more variation than typically exists in human personality research, but those from low-complexity nations were largely undergraduates who are not representative of individuals from those societies. Although we believe this aspect of sample uniformity likely worked *against* finding support for predictions – thus rendering our test conservative – future research should replicate the findings with more representative samples. For reasons discussed above, though, this endeavor will require personality researchers to confront the daunting task of constructing psychometric instruments with the ability to assess aspects of personality that can be compared across populations representing the full spectrum of human socioecological variation. This would be especially difficult if humans' manifest personality structure lacks the dimensional universality it is often claimed to possess (John et al., 2008; McCrae & Costa, 2008).

In conclusion, despite this initial study's inevitable limitations, it reports striking cross-cultural patterns that any complete theory of manifest personality covariation must be able to explain. Whereas recent debates have addressed whether positive correlations among the Big Five dimensions reflect phenotypic reality or evaluative bias (Ashton et al., 2009; McCrae et al., 2008; van der Linden et al., 2010), our perspective holds that a better question may be: Under what circumstances will distinct aspects of personality be inter-correlated (or not) to varying degrees? The present findings suggest that the socioecological complexity hypothesis provides part of the answer to this foundational question.

References

Agresti A (2013). *Categorical data analysis (3rd ed.).* Hoboken: John Wiley & Sons.

Anderson, C., Hildreth, J. A. D., & Howland, L. (2015). Is the desire for status a fundamental human motive? A review of the empirical literature. *Psychological Bulletin, 141*, 574-601.

Ashton, M. C., Lee, K., Goldberg, L. R., & De Vries, R. E. (2009). Higher order factors of personality: Do they exist? *Personality and Social Psychology Review, 13*, 79-91.

Ashton, M. C., Lee, K., & Paunonen, S. V. (2002). What is the central feature of extraversion? Social attention versus reward sensitivity. Journal of Personality and Social Psychology, 83, 245-252.

Bailey, D. H., Walker, R. S., Blomquist, G. E., Hill, K. R., Hurtado, A. M., & Geary, D. C. (2013). Heritability and fitness correlates of personality in the Ache, a natural fertility population in Paraguay. *PLoS ONE, 8*, e59325.

Benet-Martinez, V. & John, O. P. (1998). Los cincos grandes across cultures and ethnic groups: Multitrait-multimethod analyses of the big five in Spanish and English. *Journal of Personality and Social Psychology, 75*, 729-750.

Bonner, J. T. (2004). The size-complexity rule. *Evolution, 58*, 1883-1890.

Borsboom, D., Mellenbergh, G. J., & van Heerden, J. (2003). The theoretical status of latent variables. *Psychological Review, 110*, 203-219.

Carniero, R. L. (1967). Relationship between size of population and complexity of social organization. *Southwestern Journal of Anthropology, 23*, 234-243.

Cattell, R. B. (1950). Describing personality through traits. *In R. B. Cattell (Ed.), Personality: A systematic theoretical and factual study (pp. 21-24)*. New York: McGraw-Hill.

Cramer, A. O. J., Van Der Sluis, S., Noordhof, A., Wichers, M., …, Boorsboom, D. (2012). Dimensions of normal personality as networks in search of equilibrium: You can't like parties if you don't like people. *European Journal of Personality*, *26*, 414-431.

De Raad, B. (1994). An expedition in search of a fifth universal factor: Key issues in the lexical approach. *European Journal of Personality, 8*, 229 –250.

Digman, J. M. (1997). Higher order factors of the big five. *Journal of Personality and Social Psychology, 73*, 1246-1256.

Dunbar, R. I. M., Korstjens, A. H., & Lehmann, J. (2009). Time as an ecological context. *Biological Reviews, 84*, 413-429.

Feinman, G. M., & Neitzel, J. (1984). Too many types: An overview of sedentary prestate societies in the Americas. *Advances in Archaeological Method and Theory, 7*, 39–102

Figueredo, A. J., Wolf, P. S. A., Gladden, P. R., Olderbak, S., Andrzejczak, D. J., & Jacobs, W. J. (2011). Ecological approaches to personality. In D. M. Buss & P. H. Hawley (Eds.), *The evolution of personality and individual differences (pp. 210-239)*. Oxford: Oxford University Press.

Gurven, M., von Rueden, C., Massenkoff, M., Kaplan, H., & Lero Vie, M. (2013). How universal is the Big Five? Testing the Five-Factor Model of personality variation among forager–farmers in the Bolivian Amazon. *Journal of Personality and Social Psychology, 104*, 354–370.

Gurven, M., Winking, J., Kaplan, H., von Rueden, C. R., & McAllister, L. (2009). A bioeconomic approach to marriage and the sexual division of labor. *Human Nature, 20*, 151-183.

Hausmann, R. & Hidalgo, C.A. (2014). *The Atlas of Economic Complexity: Mapping Paths to*

Prosperity. Cambridge: MIT Press.

Henrich, J., Boyd, R., Bowles, C., Camerer, C., Fehr, E.,…, Tracer, D. (2005). 'Economic man' in cross-cultural perspective: economic experiments in 15 small scale societies. *Behavioral and Brain Sciences, 28*, 795-855.

Jaeggi, A. V., Hooper, P. L., Beheim, B. A., Kaplan, H., & Gurven, M. (2016). Reciprocal exchange patterned by market forces helps explain cooperation in a small-scale society. *Biology Letters*, doi:10.1016/j.cub.2016.06.019.

Jeanson, R., Fewell, J. H., Gorelick, R., & Bertram, S. M. (2007). Emergence of increased division of labor as a function of group size. *Behavioral Ecology and Sociobiology, 62*, 289-298.

John, O. P., Naumann, L. P., & Soto, C. J. (2008). Paradigm shift to the integrative big five trait taxonomy: History, measurement, and conceptual issues. In O. P. John, R. W. Robins, & L. A. Pervin, (Eds.), *Handbook of personality psychology: Theory and research (3rd ed.) (pp. 114-159)*. New York: Guilford Press.

Kaplan, H. S., Hooper, P. L., & Gurven, M. (2009). The evolutionary and ecological roots of human social organization*. Philosophical Transactions of the Royal Society of London B, 364*, 3289-3299.

Kelly, R. L. (1995). *The foraging spectrum.* Washington: Smithsonian.

Lee, K. & Ashton, M. C. (2004). The HEXACO Personality Inventory: A new measure of the major dimensions of personality. *Multivariate Behavioral Research, 39*, 329-358.

Laskowski, K. L., Montiglio, P., & Pruitt, J. N. (2016). Individual and group performance suffers from social niche disruption. *The American Naturalist, 187*, 776-785.

Lukaszewski, A. W. (2013). Testing an adaptationist theory of trait covariation: Relative bargaining power as a common calibrator of an interpersonal syndrome. *European Journal of Personality, 27,* 319-410.

McCrae, R. R. & Costa, P. T. (2008). The five-factor theory of personality. In O. P. John, R. W. Robins, & L. A. Pervin, (Eds.), *Handbook of personality psychology: Theory and research (3rd ed.) (pp. 159-181)*. New York: Guilford Press.

McCrae, R. R., Yamagata, S., Jang, K. L., Riemann, R., Ando, J., …, Spinath, F. M. (2008). Substance and artifact in the higher-order factors of the big five. *Journal of Personality and Social Psychology*, *95*, 442-455.

Mises, L. v. (1949). *Human action*. New Haven: Yale University Press.

Musek, J. (2007). A general factor of personality: Evidence for the Big One in the five factor model. *Journal of Research in Personality, 41*, 1213-1233.

Nettle, D. (2011). Evolutionary perspectives on the five factor model of personality. In D. M. Buss & P. H. Hawley (Eds.), *The evolution of personality and individual differences (pp. 5-28)*. Oxford: Oxford University Press.

Pan, W. (2001). Akaike's information criterion in generalized estimating equations. *Biometrics 57*, 120-125.

Panzar J. C., & Willig R. D. (1981). Economies of scope. *The American Economic Review 71*, 268-272.

Powers S. T. & Lehmann L. (2014). An evolutionary model explaining the Neolithic transition from egalitarianism to leadership and despotism. *Proceedings of the Royal Society of London B. 281(1791).*

Powers S.T., van Schaik C. P., and Lehmann L. (2016). How institutions shaped the last major evolutionary transition to large-scale human societies. *Philosophical Transactions of the Royal Society of London B. 371 (1687).*

Ridley, M. (2010). *The rational optimist: How prosperity evolves*. New York: HarperCollins.

Rosenberg, M. (1965). *Society and the self-image*. Princeton, NJ: Princeton University Press.

Saucier, G., Thalmayer, A. G., Payne, D. L., Carlson, R., …, Zhou, X. (2014). A basic bivariate structure of personality attributes evident across nine languages. *Journal of Personality, 82*, 1-14.

Schmitt, D. P. & Allik, J. (2005). Simultaneous administration of the Rosenberg self-esteem scale in 53 nations: exploring the universal and culture-specific features of global self-esteem. *Journal of Personality and Social Psychology, 89*, 623-642.

Schmitt, D. P., Allik, J., McCrae, R. R., Benet-Martinez, V., Alcalay, L., & Ault, L. (2007). The geographic distribution of the big five personality traits: Patterns and profiles of human self description across 56 nations. *Journal of Cross-Cultural Psychology, 38*, 173-212.

Sih, A., Mathot, K. J., Moiron, M., Montiglio, P., Wolf, M., & Dingemanse, N. J. (2015). Animal personality and state-behavior feedbacks: A review and guide for empiricists. *Trends in Ecology and Evolution, 30,* 50-60.

Stewart, F. (2013). *Capabilities and human development*. New York: United Nations Development Program.

Stieglitz, J., Gurven, M., Kaplan, H., & Hooper, P. (2013). Household task delegation among high-fertility forager-horticulturalists of lowland Bolivia. *Current Anthropology, 54,* 232-241.

Sugiyama, L. S. & Scalise-Sugiyama, M. (2003). Social roles, prestige, and health risk: Social niche specialization as a risk-buffering strategy. *Human Nature, 14*, 165-190.

Tooby, J., Cosmides, L., & Price, M. E. (2006). Cognitive adaptations for n-person exchange: The evolutionary roots of organizational behavior. *Managerial and Decision Economics, 27,* 103-129.

van der Linden, D., Nijenhuis, J. T., & Bakker, A. B. (2010). The general factor of personality: A meta-analysis of Big Five intercorrelations and a criterion-related validity study. *Journal of Research in Personality, 44*, 315-327.

von Rueden, C., Gurven, M. & Kaplan, H. (2008). The multiple dimensions of male social status in an Amazonian society. *Evolution and Human Behavior, 29*, 402-415.

von Rueden, C., Gurven, M., Kaplan, H., & Stieglitz, J. (2014). Leadership in an egalitarian society. *Human Nature, 25*, 538-566.

von Rueden, C., Lukaszewski, A. W., & Gurven, M. (2015). Adaptive personality calibration in a human society: effects of embodied capital on prosocial traits. *Behavioral Ecology, 26,* 1071-1082.

Westfall, J. & Yarkoni, T. (2016). Statistically controlling for confounding constructs is harder than you think. *PLoS One, 11*, e0152719.

Wolf, M. & Krause, J. (2014). Why personality differences matter for social functioning and social structure. *Trends in Ecology and Evolution, 29,* 306-308.

Wood, D., Gardner, M. H., & Harms, P. D. (2015). How functionalist and process approaches to behavior can explain trait covariation. *Psychological Review, 122*, 84-111.