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Title page

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Data availability statement

We have deposited datasets at OSF platform https://osf.io/3rzjd/.

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The author(s) declare that there were no conflicts of interest with respect to the authorship or the publication of this article.

Ethics approval statement

The data were collected in a manner consistent with ethical standards for the treatment of human subjects. The research was approved by the Institutional Ethics Committee of the Faculty of Philosophy, University of Novi Sad in Serbia (#02-374/15).

Author Contributions

Conceptualization: D.M., S.S., Lj.M; Methodology and Formal Analysis: S.S.; Investigation: D.M., S.S., Lj.M.; Writing – Original Draft Preparation: D.M., S.S., Lj.M, S.S.

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NA none

Abstract

Objective

This study examined whether phenotypic correlations between psychopathological dimensions and personality traits of different hierarchical levels originate from common genetic and environmental sources of variance.

Method

Participants were 386 monozygotic and 204 dizygotic twins. The Psychiatric Diagnostic Screening Questionnaire (PDSQ) was applied along with the Revised NEO Personality Inventory (NEO-PI-R). The results of the CFA confirmed the hypothesis of the internalizing and externalizing dimensions underlying PDSQ scales.

Results

The results indicated a significantly greater role of genetic compared to environmental factors in the relationship between internalizing psychopathology and personality traits. Facets of neuroticism showed positive genetic links with internalizing disorders, while negative genetic links were shown for all facets of extraversion except excitement-seeking, competence, self-discipline, achievement striving, actions, and trust. Lower-order personality traits were shown to be associated with internalizing disorders more intensively than the broader domains to which they belong, both at the phenotypic and genetic levels.

Conclusions

High neuroticism, together with several facets from the domain of extraversion and conscientiousness seems to represent an increased genetic susceptibility to the disorders from the internalizing spectrum. Results also suggest that specific environmental factors which are not shared with personality traits contribute to the internalizing symptoms.

Key words: psychopathology, personality traits, FFM, lower-order facets, twin study

Introduction

The association between psychopathology and personality has long provoked research attention (Widiger, 2011). As one of the leading dimensional models of personality traits, the Five-Factor Model (FFM) encompasses five broad domains named neuroticism (N), extraversion (E), agreeableness (A), conscientiousness (C), and openness to experience (O). FFM is hierarchical and narrows to 30 lower-order facets, so that each broad dimension encompasses six specific aspects, commonly assessed using the NEO Personality Inventory — revised (NEO-PI-R Costa & McCrae, 1992).

Numerous studies have been conducted exploring the associations between the FFM personality domains and specific mental disorders operationalized as distinct disorder entities (Walton et al., 2018). For example, associations between the FFM personality domains and anxiety (Rosellini & Brown, 2010), depression (Allen et al., 2017; de Fruyt et al., 2006), substance use (Flory et al., 2002), and personality disorders (Miller et al. 2005) demonstrated high neuroticism and low conscientiousness across all diagnostic groups. Meta-analytic data also illustrate these relationships (Kotov et al., 2010). At the level of broad domains, neuroticism, conscientiousness, and extraversion are associated with all mental disorders, while the role of agreeableness and openness is mostly negligible in the prediction of psychopathological phenomena (Walton et al., 2018).

There are findings that suggest the usefulness of narrow-level Five-Factor traits in prediction of mental disorders (Kennair et al., 2020; Walton et al., 2018). Comparison of wide-level efficiency of the NEO-FFI dimensions versus narrow-level precision of the NEO-PI-R facets is becoming an important research challenge (Baumert et al., 2017; Paunonen &

Ashton, 2001). The incremental validity of lower levels, even "nuances", such as packages of two or three items, is high, since they can be useful for describing and understanding individual differences (Mõttus et al., 2017).

More recently, the association between personality and mental disorders has been brought to the fore by popularization of the dimensional and hierarchical models of psychopathology (Kotov et al. 2021; Lahey et al., 2021). Among various hierarchical models of psychopathology, two have gained a particular visibility. One is known as the hierarchical taxonomy of psychopathology (HiTOP; Kotov et al., 2021), whereas Lahey and colleagues have proposed a causal hierarchical model (Lahey et al, 2017; Lahey et al. 2021). By reviewing the patterns of covariations among the mental disorder symptoms and maladaptive traits, Kotov et al. (2021) have suggested that at the lowest level of the hierarchy are symptoms and maladaptive traits. The symptoms that are highly correlated constitute syndromes, correlated syndromes form the subfactors, which, in turn, form spectra (e.g., internalizing and externalizing). For example, within the internalizing spectra, there are lower-order subfactors such as distress, fear, eating and sexual pathology, whereas within the externalizing spectra there are lower-order subfactors of substance use and antisocial behavior (Kotov et al., 2021). At the top of the hierarchy is the general factor of psychopathology, reflecting correlations among all symptoms (Kotov et al., 2021; Lahey, 2021).

Different from Kotov et al.'s model which is based on the phenotypic co-variations among the symptoms, Lahey and colleagues (Lahey et al., 2017; Lahey et al., 2021) have proposed a causal hierarchical taxonomy, which is based on the assumptions that some causal factors (genetic and environmental) nonspecifically influence all dimensions of

psychopathology to a different degree (i.e., pleiotropy), that different causal factors are common to a certain higher-order dimension of psychopathology, whereas some might be specific to a set of symptoms. Such causal influences are responsible for the observed pattern of phenotypic co-variations (Lahey et al., 2021), whereas a nonshared environment produces different clinical manifestations (Lahey et al., 2011). There are behavioral genetic studies which are consistent with these hypotheses. Thus, Lahey et al. (2011) found a partially common genetic origin for all mental disorders of children and adolescents. Two more classes of pleiotropic genetic influences represent the genetic risk for all internalizing or externalizing psychopathology. While the genetic basis of most conditions has been predominantly shared with other forms of psychopathology rather than unique to a particular disorder, non-shared environmental influences have been, in most cases, specific to individual conditions. Similarly, the findings of Pettersson et al. (2016) have pointed to a general genetic factor of psychopathology in adults, and two genetic factors independent of this shared genetic basis, indicating genetic risk for all disorders with psychotic features or all non-psychotic disorders. In most cases, genetic factors unique to each condition accounted for a smaller percentage of the variance. On the other hand, non-shared environmental factors operate on a less general basis, jointly influencing only disorders involving mood problems. These findings suggest that phenotypic covariations between certain forms of psychopathology are likely due to their shared genetic bases.

What is common for both taxonomies are the expectation that identifying more stable and reliable dimensions of psychopathology, rather than focusing on separate psychiatric diagnoses, and examining their relations with personality traits would facilitate understanding of the causes and mechanisms via which psychopathology develops (Lahey et al., 2021; Kotov et al., 2021). For example, by linking a certain personality disposition to a certain

psychopathology dimension, the existing knowledge about this particular trait can deepen our understanding of the psychopathology dimension with which it is correlated and vice versa (Lahey et al., 2017). It has also been suggested that different symptoms (if one, for example, considers the lowest level of the hierarchy) could be associated with different combinations of personality traits (Lahey et al., 2017), supporting the need to explore not only the relations between psychopathology and broad personality traits but their facets as well.

In contrast to an extensive literature examining phenotypic correlations between various dimensions of psychopathology, at different levels of hierarchy, and broad personality traits (Allen et al., 2017; Flory et al., 2002; Kotov et al., 2010; Rosellini & Brown, 2010), those with the focus on the lower-order personality traits are rare (e.g., Walton et al., 2018). Neuroticism (or negative emotionality) is not only associated with all diagnoses constituting the internalizing and externalizing dimensions, but it also explains the correlations between these higher–order dimensions (e.g., Barlow et al., 2014; de Graff et al., 2004; Jeronimus et al., 2016; Krueger & Markon, 2006; Ormel et al., 2013). Moreover, it is associated with the general psychopathology dimension (Caspi et al., 2014). Similarly, not only the associations between the trait of disinhibition and different externalizing diagnosis (substance use disorders, antisocial behavior) have been found (Iacono et al., 2002; Krueger et al., 2001), but also its association with the latent externalizing factor (Lahey & Waldman, 2003, 2012). Finally, in the first study which explored the relations between the lower-order facets of the Big Five model and the dimensions of psychopathology, the externalizing dimension (alcohol and drug abuse) was predicted by *excitement-seeking* from E and *self-discipline* from C (Walton et al., 2018). Two internalizing subfactors (fear and distress) were

predicted by anxiety and depression from N, gregariousness from E, aesthetics and action from O, trust and tendermindedness from A, and self-discipline from C (Walton et al., 2018).

One explanation for the observed associations between personality and psychopathology is that they have common causes i.e., belong to the same spectrum (Kotov et al., 2021; Krueger & Tackett, 2003; Tackett, 2006). The other explanation assumes that personality traits may constitute vulnerability to psychopathology (Clark et al., 1994). Nevertheless, the explanation of these associations imposes the need to extend research questions to a quantitative behavioral genetic paradigm.

Several quantitative genetic studies examined common genetic and environmental bases of the dimensions of psychopathology and broad personality traits using twins. These studies have suggested that many internalizing disorders share genetic variance with N and E (Bienvenu et al., 2007; Fanous et al., 2002; Hettema et al., 2004; Hettema et al., 2006; Hur, 2009; Kendler & Mayers, 2014). However, some disorders (for example, animal phobia) had an additional unique genetic contribution (e.g., Bienvenu et al., 2007). These studies also demonstrated that nonshared environmental factors influence these broad personality traits and internalizing disorders although environmental correlations were much smaller compared to genetic (Bienvenu et al., 2007; Hettema et al., 2006). Previous twin studies showed moderate degree of overlap between avoidant personality disorder and social phobia (Grant et al, 2005; Lampe et al., 2003; Reichborn-Kjennerud et al., 2007), personality or personality disorder and substance use (Agrawal et al., 2004; Rosenström et al, 2021) or personality and borderline personality disorder. Also, at the highest level, several studies provided evidence

for the general genetic factor of the "emotional dysregulation" (Kendler et al., 2008; Livesley et al, 1998), with the highest contribution of neuroticism.

Current study

Previous research indicates that personality provides a foundational base for the HiTOP dimensional model of psychopathology (e.g., Widiger et al., 2019), implying a common etiology of personality dimensions and mental disorders (Kotov et al., 2021). Moreover, the associations between personality and mental disorders indicate the possibility of their covariations, which may have common genetic and environmental sources of variance. However, the hierarchical structure of personality and mental disorders creates a great challenge for determining the level of organization that will be the most informative. Given the comorbidity between certain mental disorders and the findings that show genetic overlap between them, a solution that implies higher-order dimensions seemed reasonable for the psychopathology domain (e.g., Bienvenu et al., 2007; Hettema et al., 2006). In particular, the internalizing and externalizing dimensions of psychopathology seem like a promising level of hierarchy given that the former accounts for comorbidity between mood and anxiety disorders, whereas the latter explains the comorbidity between various substance use disorders and antisocial behavior. Additionally, this intermediate level seems justified given a substantial amount of empirical evidence supporting its existence and meaningful clinical correlates (e.g., Kotov et al., 2017; Kotov et al., 2021), whereas the substantive meaning of the general factor of psychopathology has been equivocal (Smith et al., 2020) with a possibility that this factor might be a statistical artifact (e.g., Bonifay et al., 2017; Littlefield et al., 2021).

To measure psychopathology in this study we used the Psychiatric Diagnostic Screening Questionnaire (PDSQ; Zimmerman & Mattia 2001) scales. In a previous study it

has been shown that among its subscales, alcohol and drug abuse/dependence define an externalizing dimension, whereas major depressive disorder, generalized anxiety disorder, post-traumatic stress disorder, panic disorder, social phobia, agoraphobia, and obsessive-compulsive disorder define a higher-order internalizing dimension (Walton et al., 2018). Also, informed by the most recent version of the HiTOP model, which is constantly updating based on empirical evidence, we expected bulimia to define the internalizing dimension. Somatization has long been considered part of the internalizing spectrum, although in recent models of psychopathology its placement remains questionable. Based on the findings in favor of its place within the internalizing spectrum (Markon, 2010; Sims et al., 2012), we hypothesize that it will fit well into the internalizing dimension.

As for the personality, we decided on lower-order traits level, considering their potential informativeness, as well as the lack of empirical data on their links to mental disorders. Previous behavioral genetic studies on the relationship between psychopathology and personality were focused exclusively on broader personality domains (e.g., Bienvenu et al., 2007; Fanous et al., 2002; Hettema et al., 2004; Kendler & Mayers, 2014). This approach often led to less specific personality profiles that were associated with a wide range of mental disorders (e.g., Heath et al., 2018). Since recent findings suggest the value of introducing the FFM facets when studying the links between personality and psychopathology at the phenotypic level (e.g., Kennair et al., 2020; Walton et al., 2018), focusing on the lower-order dimensions in behavioral genetic context is expected to also yield a more refined and nuanced understanding of their shared genetic and environmental origin.

This study explores the common and specific etiology of psychopathology and personality in order to shed light on the various factors that contribute to the development of mental disorders. The main aim is to explore common genetic and environmental sources of variance of personality traits and mental disorders that may account for their phenotypic

associations. Based on the previous results in this field (e.g., Kendler & Mayers, 2014), we expect to find substantial genetic overlap between the internalizing spectrum and neuroticism, as well as extraversion. In the absence of findings on the genetic and environmental relationship of other traits with mental disorders, our hypotheses are based on their phenotypic associations from previous research. For example, an association with conscientiousness can be expected (Kotov et al., 2010). Given the lack of evidence regarding the common genetic and environmental basis of the dimensions of psychopathology and lower-order personality traits so far, the basic research questions are whether facets share a greater common genetic variance with mental disorders than the broader NEO-PI-R dimensions. Therefore, quantitative genetic models will be tested to determine the common and specific genetic and environmental variance of personality traits and the dimensions of psychopathology. Moreover, genetic and environmental correlations at the level of NEO-PI-R facets and the dimensions of psychopathology should provide a more specific insight into the common sources of covariance.

Method

Sample

The Serbian Twin Advanced Registry has data on 427 adult twin pairs, which form the initial sample in this study. After excluding participants with missing data on at least one questionnaire, final sample includes 386 monozygotic (22.8% males; $M = 25.83$; $SD = 13.09$) and 204 dizygotic (36.8% males; $M = 23.16$; $SD = 6.24$) general-population twins from the entire territory of Serbia (regions of Vojvodina, Central Serbia, West Serbia, and Southeast Serbia). One part of the sample (45%) was examined through a computer-based platform designed for examination of twins, and for 55%, double entry was performed with a check for

mismatches and out-of-range values to avoid missing or incorrectly entered data. Participants were Caucasians (100% of participants). Most of the participants had a master's degree (43.2%), high school degree of education (24.5%) or college/bachelor's degree (19.5%), and elementary school had 1.4% participants and 3.2% were students. Self-reported socioeconomic status showed that most of the participants thought their material status was good (49.0%) or average (31.1%), while 0.9% participants thought their material status was very bad, or bad (4.2%). 14.7% of the participants saw their material status as very good. Participants were recruited from the entire territory of the Republic of Serbia through psychology students at the University of Novi Sad, and via media, social networks etc. (for the detailed procedure see Smederevac et al., 2019). Participation was voluntary, and each respondent signed informed consent. The study was approved by Institutional Ethical Review Board (# 20111020000004_e1b8). The data and data instructions for this study are available online on the OSF platform: https://osf.io/3rzjd/.

Measures

Psychiatric Diagnostic Screening Questionnaire (PDSQ; Zimmerman and Mattia, 2001) is a self-report measure designed to screen for 13 common DSM-IV Axis I disorders, includingmajor depressive disorder, bulimia, posttraumatic stress disorder, panic disorder, agoraphobia, social phobia, generalized anxiety disorder, obsessive-compulsive disorder, alcohol abuse/dependence, drug abuse/dependence, somatization, hypochondriasis, and psychosis (Zimmerman & Mattia, 2001). The PDSQ consists of 125 true/false items. Hypochondriasis was excluded from the analyses because its placement within the hierarchical structure of psychopathology is not completely resolved (e.g., Kotov et al., 2021). Finally, given our interest in the internalizing-externalizing dimensions, we did not include the psychosis and the PTSD subscales in our analyses. It should be noted that the

PDSQ does not include some essential aspects of externalizing disorders, such as antisocial behavior, but only those related to substance abuse. Therefore, the externalizing dimension is not fully covered by the measure applied. Descriptive statistics and alpha reliability are given in Supplementary material (Table A). The ranks of α reliability were from .53 for somatization to .85 for social phobia and drug abuse.

The NEO Personality Inventory-Revised (NEO-PI-R; Costa & McCrae, 1992, for Serbian adaptation see Knežević et al., 2004) is a 240-item inventory with five-point Likert scales measuring FFM traits: Neuroticism, Extraversion, Openness, Agreeableness and Conscientiousness, with each trait containing 6 facets (8 items per facet). The NEO-PI-R was applied only on the twin sample. Descriptive statistics and alpha reliabilities are given in Supplementary material (Table B). The ranks of α reliability were from .18 for Openness for Values to .76 for Conscientiousness.

Zygosity was determined by DNA analysis of the buccal swabs, tested using short tandem repeat (STR) megaplex kits, Investigator 24plex GO! (Qiagen®, Valencia, CA, USA) or GlobalFiler (Applied Biosystems®, ThermoFisher Scientific, Waltham, MA, USA) providing the two categories for each twin pair: monozygotic (MZ) or dizygotic (DZ) twin pair.

Data analysis

Descriptive analysis, phenotypic correlations, and confirmatory factor analysis were carried out using statistics open-source software (JASP, 2022). To assess the adequacy of hierarchical phenotypic solutions of the PDSQ factors, we conducted a confirmatory factor analysis (*CFA*). The models were fitted via diagonally weighted least squares (*DWLS*) using a polychoric correlation matrix (Li, 2016). Since age and sex effects can bias the twin correlation, the step before conducting further biometric analysis was to adjust all used scales

for sex and age effects, using a regression procedure proposed by McGue and Bouchard (McGue& Bouchard, 1984). Moreover, twin modeling was carried out in the "lavaan" R package (Rosseel, 2012). Univariate and multivariate twin modeling (Table 1 and 2) were conducted by using customized R scripts (Čolović, 2019) to explore the nature of the phenotypic associations between FFM dimensions and its facets and the PDSQ factors for the best-fitting phenotypic models. Genetic and environmental influences on phenotypic similarities between MZ and DZ were examined for each personality dimension and psychopathology factor by using structural equation modelling (SEM) – including univariate and multivariate biometric methods. Independent pathways (Figure 1) and common pathways (Figure 2) multivariate models (Rijsdijk & Sham, 2002) were applied in order to estimateadditive genetic (A); shared environmental(C), and non-shared environmental factors (E); and specific(s) and common (c) genetic and environmental sources ofvariance.

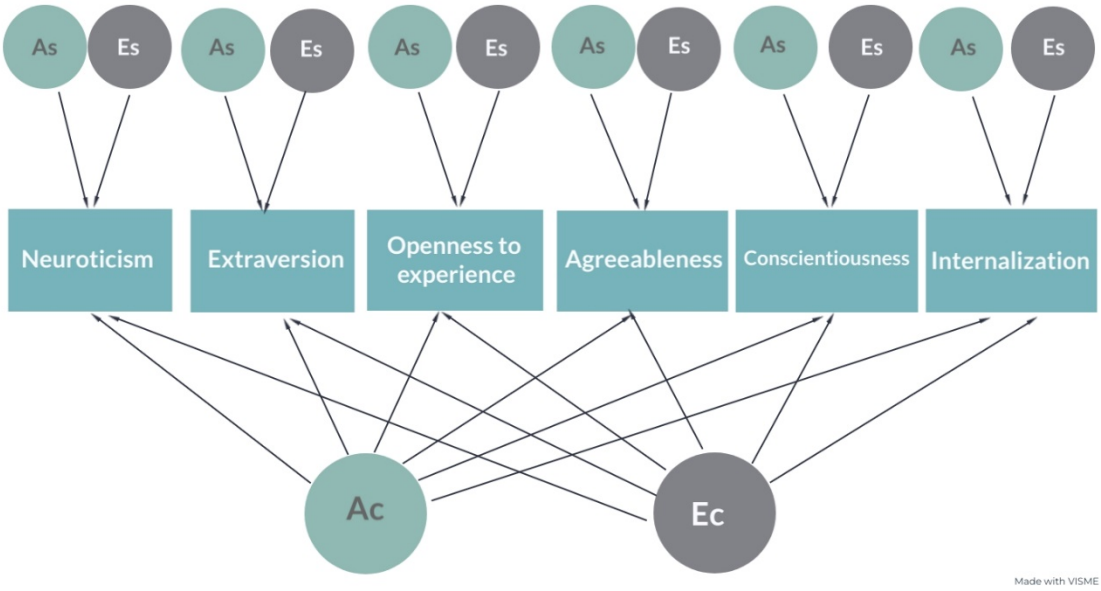

Figure 1. Independent pathway model – multivariate AE model for personality traits (NEO-PI-R) and internalization (PDSQ).

Notes. A_c − common additive genetic factor; E_c – common nonshared environmental factor; A_s – specific additive genetic factor; E_s – specific nonshared environmental factor.

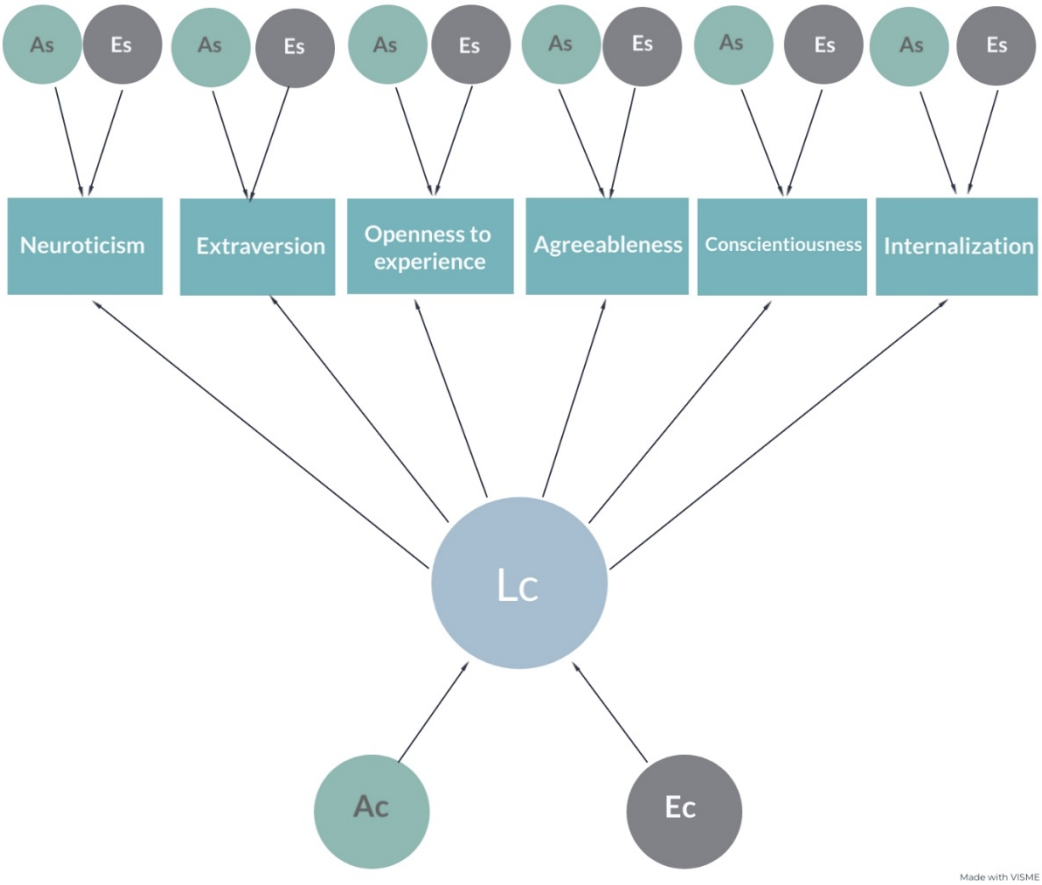

Figure 2. Common pathway model – multivariate AE model for personality traits (NEO-PI-R) and internalization (PDSQ).

Notes. A_c − common additive genetic factor; E_c – common nonshared environmental factor; A_s – specific additive genetic factor; E_s – specific nonshared environmental factor

Nested models were compared by using the χ^2-difference test; the Akaike Information Criterion (*AIC*); Comparative Fit Index and the Tucker-Lewis Index (*CFI* and *TLI* – optimal values higher than .95, acceptable higher than .90); the Root Mean square Error of Approximation (*RMSEA* – optimal values lower than .05, acceptable lower than .08); the Standardized Root Mean Square Residual (*SRMR*, with an acceptable value below .08) and Bayesian information criterion (*BIC*) with a lower value indicating better fit. Furthermore, the patterns of genetic and environmental correlations among the FFM dimensions, its facets and

PDSQ dimensions were explored using Cholesky decomposition (see for details Gardiner et al., 2019).

Results

The hierarchical phenotypic solutions for the PDSQ internalizing-externalizing model showed good model fit in the CFA (*CFI* = .96; *TLI* = .95; *RMSEA* (lower – upper bound) = .03 (.00 –.05); *SRMR* = .13). Standardized factor loadings are given in Figure3. Factor loadings ranged from .37 for bulimia and .75 for major depressive disorder in the internalizing dimension; alcohol abuse and drug abuse in the externalizing dimension also showed high factor loadings, .79 and .72, respectively.

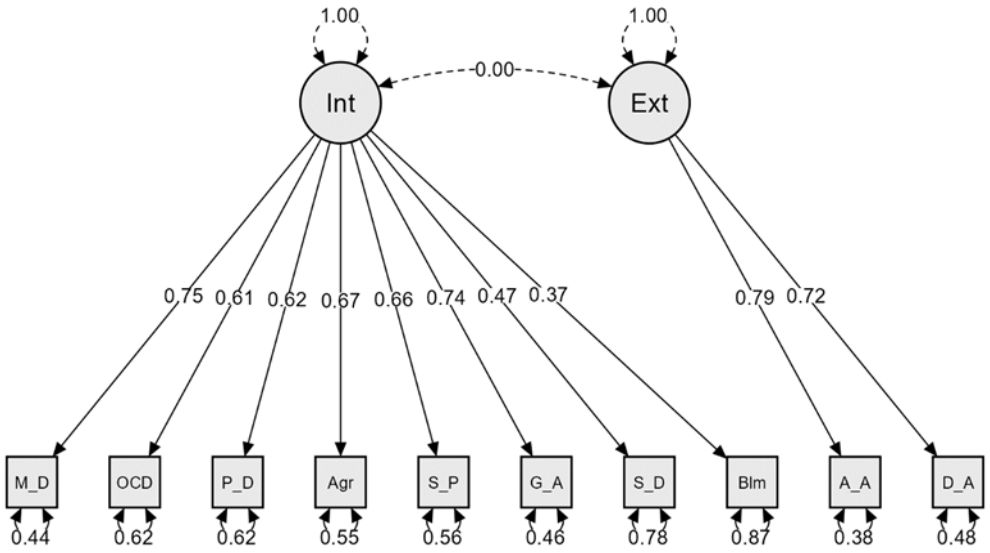

Figure 3. Model plot for the two-factor PDSQ internalizing-externalizing solution.
Notes. Int – internalizing factor; Ext – externalizing factor; M_D – major depressive disorder; OCD – opsessive-compulsive disorder; P_D – panic disorder; Agr – agoraphobia; S_P – social phobia; G_A – generalized anxiety disorder; S_D – somatization disorder; Blm – bulimia; A_A – alcohol abuse; D_A – drug abuse.

Descriptive statistics for MZ and DZ twins, cross-twin correlations among the FFM traits, its facets and the PDSQ internalizing and externalizing dimensions, as well as cross-trait correlations between the FFM traits and the PDSQ internalizing and externalizing dimensions are given in Supplementary material (Table B). Most of the variables showed normal distribution, except for the internalizing and externalizing dimension in both MZ and DZ twins (acceptable values of skewness and kurtosis fall between − 3 and + 3: Brown, 2006). The statistics revealed a positively skewed (Skewness 6.27) and extremely leptokurtic distribution of the externalizing dimension (Kurtosis 43.62), especially in the MZ twin subsample. Although asymmetric distributions of psychopathological traits are expected for the non-psychiatric population, such a significant deviation from the normal distribution regarding externalizing disorders indicates that behaviors covered by this dimension are rare among the participants, and with many outliers. This deviation might partially explain extremely low phenotypic correlations of the externalizing dimension with the personality traits. Results suggested that the externalizing dimension does not qualify for behavioral-genetic model testing, so it is excluded from further analyses.

Correlations among MZ twins were systematically higher than for DZ twins (except for anxiety, warmth, and internalizing dimension), suggesting that genetic effects might be significant for these dimensions. On the other hand, cross-trait correlations showed that none of the correlations between the FFM traits or facets, and the externalizing dimension were significant, in contrast to the correlations with the internalizing dimension. The internalizing dimension was positively associated with the broad domain of neuroticism (r = .571) and all its facets, mildly negatively with extraversion (r = -.183) and its facets gregariousness (r = -.194), warmth (r = -.204), and assertiveness (r = .134), mildly positively with openness'

facets aesthetics (r = .126) and feelings (r = .110), mildly negatively with trust (r = -.149) from the agreeableness domain, as well as with the conscientiousness (r = -.168) and the three of its facets: competence (r = -.243), self-discipline (r = -.217), and deliberation (r = -.129). Results of univariate genetic analyses for all dimensions presented in Table 1 showed that, based on the best model fit and parsimony, AE models (additive genetic and nonshared environmental effects) were most adequate and were used in subsequent multivariate genetic models.

Table 1

Univariate model fit statistics for the NEO-PI-R traits and internalization factor

Traits	Model	χ^2	*df*	CFI	TLI	RMSEA	SRMR	AIC	BIC
Neuroticism	AE *	0.77	4.00	1.00	1.04	0.00 (0.00−0.02)	0.03	1538.10	1559.80
	ACE	0.59	3.00	1.00	1.04	0.00 (0.00−0.06)	0.03	1539.90	1565.20
	ADE	0.77	3.00	1.00	1.04	0.00 (0.00−0.08)	0.03	1540.10	1565.40
Extraversion	AE *	2.12	4.00	1.00	1.01	0.00 (0.00−0.10)	0.07	1538.10	1559.80
	ACE	2.00	3.00	1.00	1.01	0.00 (0.00−0.12)	0.06	1539.90	1565.20
	ADE	2.12	3.00	1.00	1.01	0.00 (0.00−0.13)	0.07	1540.10	1565.40
Openness	AE *	0.98	4.00	1.00	1.03	0.00 (0.00−0.05)	0.03	1516.00	1537.80
	ACE	0.98	3.00	1.00	1.02	0.00 (0.00−0.09)	0.03	1518.00	1543.40
	ADE	0.49	3.00	1.00	1.03	0.00 (0.00−0.05)	0.03	1517.50	1542.90
Agreeableness	AE *	4.78	4.00	0.99	0.99	0.04 (0.00−0.14)	0.07	1520.30	1542.10
	ACE	4.78	3.00	0.97	0.98	0.07 (0.00−0.17)	0.07	1522.30	1547.70
	ADE	3.78	3.00	0.99	0.99	0.04 (0.00−0.16)	0.07	1521.30	1546.70
Conscientiousness	AE *	0.50	4.00	1.00	1.02	0.00 (0.00−0.00)	0.02	1538.10	1559.80
	ACE	0.14	3.00	1.00	1.02	0.00 (0.00−0.00)	0.01	1539.90	1565.20
	ADE	0.50	3.00	1.00	1.02	0.00 (0.00−0.05)	0.02	1540.10	1565.40
Internalization	AE *	22.27	4.00	0.62	0.81	0.24 (0.15−0.34)	0.22	866.71	885.01
	ACE	19.34	3.00	0.66	0.77	0.26 (0.16−0.38)	0.22	865.78	887.13
	ADE	22.27	3.00	0.60	0.73	0.29 (0.18−0.40)	0.22	868.71	890.06

Notes. ACE, ADE – full common pathways model; AE – reduced common pathways model.

* – The best model fitting based on fit parameters and parsimony.

Testing the multivariate independent and common AE models showed a better fit for the independent AE model (χ^2/df = 1.62; *CFI* = .847; *TLI* = .847; *RMSEA* = .090; *SRMR* = .129; *AIC* = 5219.7; *BIC* = 5366.1), compared to the common AE model (χ^2/df = 2.04; *CFI* = .739; *TLI* = .746; *RMSEA* = .115; *SRMR* = .134; *AIC* = 5274.5; *BIC* = 5408.7).Moreover, common additive genetic effects are highest for internalization (.50) and neuroticism (.47), and common environmental effects are highest for openness to experience (.25). On the other hand, specific genetic effects are highest for extraversion and agreeableness (.54) and specific environmental effects are highest for internalization (.43) (Table 2).

Table 2

Additive genetic (A) and nonshared environmental effects (E) on five-factor dimensions and internalization

	A_c	E_c	A_s	E_s	A	E
Neuroticism	.47	.14	.00	.39	.47	.53
Extraversion	.03	.18	.54	.25	.57	.43
Openness to experience	.02	.25	.45	.28	.47	.53
Agreeableness	.01	.05	.54	.40	.55	.45
Conscientiousness	.07	.18	.50	.24	.57	.43
Internalization	.50	.00	.07	.43	.57	.43

Notes. Common (A_c) and specific (A_s) genetic, common (E_c) and specific (E_s) environmental effects; A – additive genetic effects in total; E – nonshared environmental effects in total. Parameter estimates derived from the best fitting model.

Table 3 shows genetic and environmental correlation between the internalization dimension and the FFM traits and its facets.

Table 3

Genetic and environmental correlations between the NEO-PI-R dimensions, its facets, and the internalizing factor

NEO-PI-R trait/facets	r_G	r_E
NEUROTICISM	.904** (.888/.918)	.199** (.120/.275)
Anxiety	.864** (.842/.883)	.227** (.149/.302)
Hostility	.734** (.694/.769)	.199** (.120/.275)
Depression	.724** (.683/.760)	.033 (-.048/.113)
Self-consciousness	.724** (.683/.760)	.068 (-.013/.148)
Impulsiveness	.431** (.363/.494)	.236** (.158/.311)
Vulnerability	.563** (.505/.616)	.035 (-.046/.115)
EXTRAVERSION	-.323** (-.393/-.249)	.106* (.025/.185)
Warmth	-.336** (-.406/-.262)	-.006 (-.087/.075)
Gregariousness	-.330**(-.400/-.256)	.026 (-.055/.106)
Assertiveness	-.296** (-.368/-.220)	.102* (.021/.181)
Activity	-.270** (-.343/-.193)	.161** (.081/.239)
Excitement seeking	-.073 (-.153/.008)	.029 (-.052/.109)
Positive emotions	-.349** (-.418/-.276)	.127** (.047/.206)
OPENNESS TO EXPERIENCE	.088 (.007/.167)	.075 (-.006/.155)
Fantasy	-.022 (-.102/.059)	.055 (-.026/.135)
Aestetics	.159** (.079/.237)	.142** (.062/.220)
Feelings	.174** (.095/.251)	.116** (.036/.195)
Actions	-.262** (-.336/-.185)	.043 (-.038/.123)
Ideas	.126** (.046/.205)	.019 (-.062/.100)

Values	-.067 (-.147/.014)	-.026 (-.106/.055)
AGREEABLENESS	.046 (-.035/.126)	-.121** (-.200/-.041)
Trust	-.299** (-.371/-.224)	.044 (-.037/.124)
Straightforwardness	.034 (-.047/.114)	-.014 (-.095/.067)
Altruism	.123** (.043/.202)	.028 (-.053/.108)
Compliance	.012 (-.069/.093)	-.183** (-.260/-.104)
Modesty	.206** (.127/.282)	-.188** (-.265/-.109)
Tender mindedness	.082 (.001/.162)	-.084 (-.164/-.003)
CONSCIENTIOUSNESS	-.236** (-.311/-.158)	-.045 (-.125/.036)
Competence	-.339** (-.408/-.265)	-.125** (-.204/-.045)
Order	.055 (-.026/.135)	.004 (-.077/.085)
Dutifulness	-.118** (-.197/-.038)	.060 (-.021/.140)
Achievement striving	-.232** (-.307/-.154)	.057 (-.024/.137)
Self-discipline	-.292** (-.364/-.216)	-.051 (-.131/.030)
Deliberation	-.150** (-.228/-.070)	-.075 (-.155/.006)

Notes. Uppercase letters suggesting the trait level of the FFM traits.

r_G – genetic correlation; r_E– environmental correlation. Confidence intervals are given in parentheses(/).

** p < .01; * p < .05.

Discussion

The main aim of this study was to explore sources of the observed relations between personality traits and psychopathological dimensions by examining their common genetic

and environmental variance. The basic assumption based on the hierarchical structure of psychopathology was that many mental disorders share the same genetic source of variance, which allows examination of the higher-order dimension (Bienvenu et al., 2007; Hettema et al., 2006). The results of the CFA of the PDSQ scales were congruent with this widely accepted and empirically supported idea that mental disorders are organized along higher-order dimensions of the internalizing and externalizing spectra (Kotov et al., 2021). The first factor is very broadly defined and covers generalized anxiety disorder, major depressive disorder, social phobia, panic disorder, agoraphobia, bulimia, OCD, and somatization disorder, clearly corresponding to the spectrum of internalizing disorders. Unlike this dimension, the second factor was quite narrowly defined and includes only alcohol and drug abuse, behaviors that belong to the externalizing disorder's spectrum. This result indicates the underrepresentation of the externalizing spectrum in the PDSQ, since some important forms of disorder, such as antisocial behavior, are missing. The limited coverage of relevant phenomena seriously threatens the assessment of the externalizing spectrum using the PDSQ. Although an analysis of the PDSQ is beyond the scope of this paper, it is necessary to point out its lesser suitability in the context of theories of psychopathology, especially since earlier research has also emphasized limitations of this questionnaire as a screening tool, due to the exclusion of many disorders (Rush et al, 2013; Urbanoski et al., 2015). Therefore, this unequal representation of internalizing and externalizing disorders compromised the testing of shared genetic and environmental sources of variation with personality traits, which had to be focused exclusively on the internalizing spectrum.

Relationships between personality traits and internalizing symptoms have been demonstrated in many previous studies (Allen et al., 2017; Kotov et al., 2010; Rosellini & Brown, 2010), with a special emphasis on the compelling contributions of neuroticism, extraversion, and conscientiousness (Walton, 2018). The results of our study confirm these

relational patterns, showing that negative emotionality, low sociability, negative self-efficacy, poor voluntary control, suspicion, and distrust may be understood as personality dispositions for manifesting internalizing behavior. However, going beyond the examination of phenotypic relationships, our main goal was to examine whether the NEO-PI-R facets share more genetic and environmental variance with the psychopathology dimensions than the higher-order personality traits.

Results of the multivariate behavioral genetic model showed that internalizing disorders share almost entirely genetic variance with the five personality domains. The specific genetic variance for this dimension is negligible. This result implies a crucial role of personality traits in the emergence and maintenance of internalizing symptoms. Given a complete overlap between the genetic basis of neuroticism and the other dimensions in the model, and predominantly specific genetic factors underlying other personality traits, the model suggests, in line with previous studies (Bienvenu et al., 2007; Fanous et al., 2002; Hettema et al., 2004), that neuroticism represents most of the personality-based genetic liability for internalizing psychopathology. Another important source of variation is the environment, and results show that specific environmental effects are crucial for internalizing behaviors and agreeableness. Although the role of the specific environment is important for other personality dimensions as well, the common environmental effects cannot be neglected. In other words, although internalizing behaviors share significant genetic variance with personality dimensions, particularly neuroticism, they are highly dependent on individualized, specific environmental experiences. This tendency is also confirmed in the pattern of genetic and environmental correlations between internalizing disorders and personality traits.

Namely, the observed patterns of phenotypic associations stem much more from common genetic variance than an environmental one, which is consistent with the previous findings (Hettema et al., 2006). It is possible that specific experiences in the environment represent a trigger only for the emergence of internalizing disorders, acting selectively and without a dominant influence on other traits. Therefore, internalizing disorders have extremely small environmental correlations with personality traits. This particularly applies to neuroticism and its facets - the genetic correlations of the domain and most facets with internalizing dimension are very high, while the environmental ones are low for anxiety, hostility, and impulsiveness, or absent, for depression, self-consciousness, and vulnerability. Also, moderate negative genetic correlations with the internalizing dimension are shown for all facets of extraversion, except excitement-seeking, while the environmental ones are negligible, except for activity. Despite the genetic correlation, there is a possibility that lack of activity, as an important environmental factor, may facilitate the emergence of internalizing strategies. There is a noticeably similar pattern regarding the domain and facets of conscientiousness. The negative genetic correlation with competence, achievement striving, and self-discipline implies the importance of self-perception of potential and resources for achieving goals. In other words, the experience of incompetence can reduce cognitive and emotional capacities to face different challenges.

It is important to emphasize that agreeableness and openness, which are not most often associated with internalizing disorders (Walton et al., 2018), include facets that can nevertheless provide an important contribution to their etiology. For example, a negative genetic correlation with trust and a positive correlation with modesty points to important

aspects of interpersonal behavior that may shape the direction of symptoms. Also, the negative genetic association between actions and the internalizing dimension points to another source of predispositions to avoid actively coping with sources of tension.

In general, these findings clearly indicate the important role of genetic, and the limited role of environmental factors in the covariation of personality traits and internalizing disorders. The common genetic basis is particularly evident in the case of neuroticism. It probably represents a genetic liability for negative emotionality, increased emotional reactivity and tension and indicates the dimension of neuroticism as the main factor of genetic vulnerability for internalizing behavior (Bienvenu et al., 2007). In the case of extraversion, this common hereditary basis may refer to the genetically increased arousal of the central nervous system resulting in social withdrawal, and in the case of conscientiousness, the hereditary weaker capacity for control of goal-oriented behavior. The results also imply the importance of a narrow level of personality traits in considering the etiology of psychopathological disorders, due to their greater informativeness and plausibility of explanations. Also, the exclusion of agreeableness and openness from research designs that have the ambition to consider the relationship between psychopathological symptoms and personality traits has no justification in the empirical findings.

The results suggest the great importance of environmental influences for the etiology of internalizing disorders. However, since these disorders share with personality traits primarily genetic sources of variance, it remains unknown what specific environmental triggers are necessary for the adoption of internalizing behaviors. Still, the results suggest that certain non-shared environmental factors may be, though to a small extent, common to some personality traits and internalizing disorders. Also, the assumption about the important role of

gene-environment correlations in the obtained results should not be ignored (Perlstein & Waller, 2022).

These results are consistent with the hypothesis of a common etiology of personality traits and psychopathology (de Bolle et al., 2012; Kotov et al., 2021; Widiger et al, 2019). Although this hypothesis does not exclude other possible patterns of associations, such as the "vulnerability" (Clark et al., 1994) or "scar" (Rohde et al. 1990) hypotheses, it acts as a plausible explanation considering the obtained results. Additionally, testing other hypotheses would require a longitudinal design.

There are limitations arising from this study that do not allow a simple generalization of the results. First, the fact that the PDSQ does not cover the entire spectrum of psychopathological symptoms and significant deviations in the distribution contributed to the exclusion of the externalizing factor from the quantitative genetic analysis, which limits insight into a wider spectrum of mental disorders. However, pointing out the problems with the PDSQ may facilitate future research on this topic. Second, the reliability of some facets of the NEO-PI-R are extremely low and may compromise the results. The genetic and environmental sources of variance are in line with previous studies with this questionnaire (Riemann & Kandler, 2010), indicating that there is no discrepancy in heritability estimates. Also, previous cross-cultural behavioral genetic studies with NEO-PI-R on our sample (Smederevac et al., 2020) showed a similar pattern of genetic and environmental contribution to the variance of all FFM dimensions, which indicates that culture does not have a significant influence on the genetic and environmental variance of personality traits, although different patterns of genetic and environmental correlations indicated to possible subtle differences in item translation, testing conditions, and measurement error. ~~However,~~ Since the non-shared environment in behavioral genetic models can also include measurement error, the general question of the

quality of personality questionnaires remains open. Third, twin studies that rely on the voluntary participation of subjects face considerable challenges, from sample size to recruitment bias (Lykken et al., 1987). Therefore, it is likely that people who are prone to breaking social norms, mainly related to externalizing disorders, will participate less, which contributes to the distribution of externalizing disorders, not reflecting the characteristics of the general population. Fourth, sample size is usually an issue in twin studies, as the recruitment of subjects is very demanding, while biometric models require large samples to ensure statistical power. In this study, the power for the conducted tests is not known, although the sample of 592 twins likely allows testing of the AE models (Sham et al., 2020), as well as genetic and environmental correlations.

Despite the limitations, there are some important implications of the results of this study. Previous research on the sources of covariations between broad personality dimensions and internalizing disorders has mainly focused on the role of neuroticism and extraversion (Bienvenu et al., 2007; Fanous et al., 2002; Hettema et al. 2004; Hettema et al., 2006). However, an important finding of this study is that narrow-level facets of all NEO-PI-R dimensions are more convincingly related to internalizing disorders than are broader domains. The importance of hierarchically lower traits for the understanding of psychopathology is relevant for all domains except neuroticism, which realizes substantial phenotypic and genetic associations with internalizing disorders at both the broad and narrow levels. This result provides a contribution to the accumulation of evidence on the importance of all personality domains for the development of mental disorders, with special emphasis on narrow-level facets (Kennair et al., 2020). In other words, susceptibility to developing internalizing symptoms may depend on specific facets, such as actions from the domain of openness, or trust and modesty from the domain of agreeableness.

Although the significantly greater role of genetic factors in the relationship between personality and internalizing psychopathology compared to environmental factors may seem confusing, this result must not be taken out of context. Namely, unshared environmental factors have a significant role in shaping internalizing disorders, but exclusively due to specific environmental effects. Therefore, environmental influences common to personality traits appear trivial. This result raises an important question about the nature of the environmental triggers that are specific to the development of internalizing symptoms. This type of external influence is especially intriguing considering possible pleiotropy that may explain genetic overlaps between internalizing disorders and personality traits (Lahey et al., 2011; Pettersson et al., 2016). The assumption that internalizing levels of adaptation must be sought outside the usual environment relevant to the development of personality traits must be examined in future research, with a more thorough consideration of the specifics of the dysfunctional environment. There are important implications of these results for understanding the etiology of mental disorders, since the most important finding is that mental disorders share all genetic variance with personality traits and that very specific environmental factors, which are not registered in the usual variations of personality traits, play a crucial role in their development. In other words, there are specific environmental influences that represent a trigger for the onset and development of internalizing disorders. The result that there is no specific genetic basis of psychopathological symptoms indirectly implies their dimensional basis. Finally, despite the focus on internalizing disorders, the results of this study indirectly support the hypothesis of the internalizing and externalizing spectra as the dimensions underlying the covariation of different mental disorders (Kotov et al., 2021).

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