Journal of Research in Personality 97 (2022) 104201

Contents lists available at ScienceDirect

Journal of Research in Personality

journal homepage: www.elsevier.com/locate/jrp

Etiology of basic psychological needs and their association with personality: A twin study

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ARTICLE INFO

Keywords:
Basic psychological needs
Self-Determination Theory
Personality Traits
Five-factor model
Behavior Genetics
Heritability
Twin study

ABSTRACT

Self-determination theory postulates that three basic psychological needs – need for autonomy, competence, and relatedness – drive our motivation. However, little is known about the sources of individual differences in basic psychological needs, and about its shared etiology with personality. Self-report data on basic psychological needs and five-factor personality traits were collected in a sample of 668 Croatian twins. Results indicate substantial heritability of basic psychological needs, while environmental influences were non-shared by family members. Three psychological needs substantially correlated with extraversion and neuroticism, and some need- specific overlaps were found with conscientiousness, openness, and agreeableness. Phenotypic overlap of the basic psychological needs with personality was mainly due to the common genetic effects, while their environmental influences were largely independent.

1. Introduction

1.1. Basic psychological needs

Psychological needs are motivational concepts. Within a general motivational cycle framework, needs drive our behavior to achieve goals that will satisfy them. Humans have many needs, but not all are equally important for optimal psychological functioning and well-being. Psychological needs that are essential for optimal human functioning are postulated within Basic Psychological Needs Theory (BPNT; Deci & Ryan, 2000; Ryan & Deci, 2002), an important sub-theory within a broader Self-Determination Theory framework (SDT; Ryan & Deci, 2000, 2008), which is an extremely fruitful motivational macro-theory in the field of positive psychology.

1.1.1. Self-Determination theory

SDT was initially built upon four intertwined mini-theories, but has further been expanded to include six mini-theories explaining specific aspects of motivational functioning (Deci & Ryan, 2012, 2014). We will provide only a very brief theoretical overview relevant to this study (for more details, see Deci & Ryan, 2012, 2014; Ryan & Deci, 2008). Cognitive evaluation theory (CET) focuses on the effects of extrinsic factors that may lead to enhancement/decrease in intrinsic motivation via the perceived locus of causality and the satisfaction/thwarting of autonomy; Causality orientations theory (COT) focuses on relatively stable motivational concepts of amotivation, controlled motivation, and autonomous motivation, with autonomous motivation potentially leading to higher levels of intrinsic motivation and satisfaction of basic psychological needs; Organismic integration theory (OIT) focuses on different types of extrinsic motivation along the self-determination continuum and the process of internalization, which may result in initially externally motivated behaviors becoming more autonomous; Goal content theory (GCT) focuses on intrinsic versus extrinsic life goals, with intrinsic goals potentially leading to higher satisfaction of basic psychological needs satisfaction and higher well-being; Relationships motivation theory (RMT) focuses on achieving higher quality of close relationships via satisfaction of all three basic psychological needs (Deci & Ryan, 2012, 2014). Since this study is based on SDT, more precisely on the mini-motivation theory called Basic psychological needs theory (BPNT), we will address this theory in more detail.

1.1.2. Basic psychological needs theory

Ryan and Deci (2008, p. 657) define basic psychological needs "as a nutriment essential for psychological growth, integrity, and wellness". Within BPNT there are three basic and universal psychological needs that energize motivational behavior of all humans and are described as *psychological nutriments* – the need for autonomy, competence, and relatedness. Although these needs are postulated as innate human

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https://doi.org/10.1016/j.jrp.2022.104201
Received 4 June 2021; Received in revised form 16 January 2022; Accepted 25 January 2022
Available online 30 January 2022

universals, there are individual differences in the degree of their satisfaction within a particular population. These individual differences are of crucial importance because need satisfaction predicts many relevant life outcomes and is associated with well-being and optimal functioning (Vansteenkiste & Ryan, 2013).

Ryan and Deci (2008) describe the *need for autonomy* as a self-organized and self-endorsed behavior, which originates from within us and is not controlled by others. The need for autonomy is satisfied when a person makes their own choices regarding their life, and it is defined by its subjective aspects – the perceived locus of causality and the perceived possibility of free choice/will. Satisfying the need for autonomy also leads to a sense of integrity between one's behavior, thoughts, and feelings (Vansteenkiste et al., 2020). The *need for competence* represents feeling effective in one's actions while experiencing opportunities to exercise, expand, and express one's capacities. The need for competence is activated when a person encounters an optimal challenge and is satisfied by receiving positive feedback about one's achievement. Therefore, this need is related to the experience of mastery and effectiveness in the activities that someone is engaging in. The *need for relatedness* represents a feeling of connectedness and a sense of belonging within others whom one cares for and who care for them. The need for relatedness is activated when a person interacts with others but is satisfied only when one perceives that the other person values their true self and is concerned for their well-being.

1.1.3. Research on basic psychological needs

These three basic psychological needs were first operationalized by contextually specific need satisfaction scales, with contexts such as relationships (La Guardia et al., 2000), work (Deci, et al., 2001), or video games (Ryan et al., 2006). Eventually, a general basic need satisfaction scale was developed (Gagné, 2003). The satisfactory psychometric properties of these scales have been confirmed (e.g., Chen et al., 2015; Van den Broeck et al., 2010), but there have also been some criticisms and suggestions for future scale improvements (Johnston & Finney, 2010). It is important to distinguish between the "perception" of one's needs and individual differences in the "satisfaction" of basic psychological needs. BPNT postulate that individual differences in need satisfaction (rather than in the perception of one's needs) are psychologically relevant. Thus, basic psychological needs are present in all humans, but there are individual differences in satisfaction of those needs that predict important life outcomes. These individual differences are measured by the Basic need satisfaction scale (Deci & Ryan, 2000; Gagné, 2003).

Psychological needs, their correlates, and outcomes have been studied extensively over the past two decades, focusing on need satisfaction in diverse life domains (Milyavskaya & Koestner, 2011), from education (e.g., Jang et al., 2012; Ratelle et al., 2013), healthcare (e.g., Ng et al., 2012; Ntoumanis et al., 2020), romantic relationships (e.g., Hadden et al., 2014; La Guardia & Patrick, 2008), work/organizational behavior (e.g., Walker & Kono, 2018; Wandeler & Bundick, 2011), to sports (e.g., Jowett et al., 2016; Teixeira et al., 2012). Thus, the theoretical, as well as empirical importance of predicting relevant life outcomes based on the satisfaction of basic psychological needs is well established. However, the etiology of individual differences in the degree of need satisfaction, from a behavioral genetic perspective, has not yet been empirically investigated.

1.2. Basic psychological needs and personality traits

Personality traits are broad constructs that reflect typical patterns of behavior, cognition, and affect that are relatively stable over time and across different situations. On the other hand, needs consist of one's goals and desires that motivate behavior and are therefore conceptually distinct from traits (Şimşek & Koydemir, 2013). Ryan & Deci (2008) state that needs are not traits because their satisfaction meaningfully fluctuates with changing environmental supports and the person's capacity to find satisfaction. Compared to personality traits, basic psychological needs are more prone to change due to their expected dependence on environmental changes relevant to their degree of satisfaction. Although personality traits are relatively stable over time with an average test–retest stability coefficient around 0.50 (Roberts & DelVecchio, 2000) and moderately heritable (Vukasović & Bratko, 2015; Bratko et al., 2017), they are neither "set in stone" nor completely predetermined by our genes. On the contrary, a very propulsive research question in the field of personality is their stability (e.g., Bratko & Butković, 2007; Damian et al., 2019; Hicks et al., 2012), as well as their change (e.g., Bleidorn et al., 2020; Jayawickreme et al., 2021; Roberts et al., 2017).

Clearly, both needs and traits are relevant constructs for understanding human behavior and related life outcomes. SDT, more precisely the mini-motivation theory called the Cognitive Evaluation Theory (CET; Ryan & Deci, 2008), states that motivation has an important influence on personality development. However, we offer a slightly different view on the joint role needs and traits play in modelling our behavior, a view that includes bidirectional causality. We agree that needs satisfaction, as well as intrinsic motivation, may influence personality development, but we also believe that personality may influence the frequency of a behavior that would lead to need satisfaction. For example, an emotionally stable person will choose a course of action more freely, will endure possible criticism more easily, and consequently satisfy the need for autonomy to a greater degree. A student with a high level of conscientiousness is likely to study regularly, acquire higher grades, and consequently, satisfy the need for competence to a greater degree. A more agreeable person will invest more time and effort in interpersonal relationships and consequently satisfy the need for relatedness to a greater degree.

Conceptually, one would expect a certain overlap between needs and traits. For example, the degree of satisfaction of all three needs depends on interaction with the environment and (un)satisfying outcomes, which is also true for personality traits that are structurally defined by emotional reactivity – neuroticism and extraversion (e.g., Carver & White, 1994; Larsen & Ketelaar, 1991); the need for competence shares a form of specific "achievement goal" with conscientiousness (e.g., Bakker et al., 2012; Dumfart & Neubauer, 2016); the need for relatedness shares a form of specific "interpersonal goal" with extraversion and agreeableness (e.g., Gallo & Smith, 1998; Wiggins, 1979).

1.2.1. Theoretical integration

Recently, there have been efforts to identify unifying principles and provide a theoretical framework of SDT and personality research (Ryan et al., 2019; Sheldon & Prentice, 2019), or more specifically – an attempt to provide theoretical integration of the motivational constructs operationalized by the SDT with personality traits, operationalized by the Whole Trait Theory (WTT; Prentice et al., 2019) and the Personality System Interactions theory (PSI; Koole et al., 2019). Prentice et al. (2019) state that we may consider personality traits as tools for satisfying basic psychological needs, and further propose links between SDT and the Big Five. Based on the BPNT, authors expect that "Trait enactments will be correlated with need satisfaction. […] The relations will *not* be such that there are exclusive links between particular traits and particular needs, because traits can be used as tools for a variety of goal contents" (Prentice et al., 2019, p. 65). At the same time, authors derive somewhat different expectations of SDT-Big Five links based on two other SDT mini-theories: with the need for autonomy showing negative correlations with neuroticism and positive correlations with conscientiousness and extraversion (Organismic Integration Theory, OIT; Ryan & Deci, 2008), and positive correlation with openness (Causality Orientation Theory, COT; Ryan & Deci, 2008).

1.2.2. Research on phenotypic overlap between needs and traits

Since both needs and traits influence our behavior, it is somewhat surprising that there have not been many studies simultaneously assessing both sets of variables. Most empirical studies focused either on

the motivational or the dispositional perspective, and the ones that included both sets of variables, often did not report correlations on all personality traits, operationalized mostly within the Big Five (Goldberg, 1990) and the Five-Factor Model (Costa & McCrae, 1992), and three basic psychological needs (e.g., Demirbaş-Çelik & Keklik, 2019; Tavernier et al., 2019; Yang et al., 2018). However, those studies that did report empirical data on the needs-traits relationship are a highly valuable source for the formulation of our hypothesis because they show substantial correlations with personality traits (Andreassen et al., 2010; Bratko & Sabol, 2006; Nishimura & Suzuki, 2016; Şimşek & Koydemir, 2013; Sulea et al., 2015; Volodina et al., 2019). Van den Broeck et al. (2016) conducted a *meta*-analysis on basic psychological needs satisfaction specifically in the work context, and also found only a modest number of primary studies including correlational data on basic psychological needs and specific personality traits. The most consistent findings of the associations between basic psychological needs and personality traits are negative correlations of all three needs with neuroticism, and positive with extraversion, which may be categorized as mostly small to moderate effect sizes (Cohen, 1992). However, some specific need-trait correlations seem to be more stable and substantial across all studies. The need for autonomy was consistently correlated with neuroticism, extraversion, and agreeableness, and less consistently with conscientiousness and openness. The need for competence was correlated with neuroticism, extraversion, and conscientiousness, while correlations with agreeableness and openness were less consistent or marginal. The need for relatedness was correlated with neuroticism, extraversion, and agreeableness, while substantial correlations with conscientiousness and openness were obtained only in a few studies.

1.3. Etiology of basic psychological needs and personality traits

1.3.1. Genetic and environmental contributions to individual differences

Heritability is a population-based estimate of relative genetic contributions to individual differences in a specific phenotype or an observable characteristic. This statistical parameter (h^2) varies from 0 to 1 (or 0 to 100%), with higher value indicating a larger genetic contribution or genetic effect-size. The most fundamental distinction in the etiology of individual differences is on the genetic *vs.* environmental contributions to individual differences. The genetic component can further be decomposed into additive (*a*) and non-additive (*na*) genetic influences, which includes dominance (*d)* and epistatic (*i)* effects, while the environmental component can be decomposed into shared (*c*) and non-shared (*e*) environmental component (Knopik et al., 2017).

When examining a specific trait or a characteristic (e.g., intelligence) from the behavioral-genetic perspective, we measure or assess the phenotype (e.g., the IQ score on a standardized test), but are interested in the relative contributions of genes and environment that contribute to individual differences in a phenotype of interest. To do this, we must analyze data of participants who are genetically or environmentally informative (e.g., monozygotic and dizygotic twin pairs, biological parents-offspring, parents-adopted offspring), or apply the molecular-genetic approach, which assesses individual differences in genotypes directly. This field is naturally much more complex, but we will limit our introduction to basic terms necessary for this study (for details see Knopik et al., 2017; Plomin & Rende, 1991).

The question of human traits' etiology has been of interest for almost a century. Polderman et al. (2015) conducted a large *meta*-analysis of diverse human traits, based on more than 2500 twin studies, and concluded that the *meta*-analyzed average heritability estimate is 49%, meaning that genetic and environmental contribution to individual differences is similar. It is important to stress that these estimates varied substantially for different domains and traits. Apart from such global estimates, there have also been *meta*-analyses with different behavioral-genetic methods as inclusion criteria, focusing on the heritability of various specific phenotypes, e.g., cognitive ability (Briley & Tucker-Drob, 2013), educational achievement (de Zeeuw et al., 2015), autism (Tick et al., 2016), well-being (Bartels et al., 2015; Nes & Røysamb, 2015), or self-control (Willems et al., 2019).

1.3.2. Research on personality traits' and needs' etiology

For personality as a phenotype, the *meta*-analysis of twin, adoption, family, and twin-family study designs showed an average heritability estimate of 0.40; however, this estimate was substantially moderated by study design, with twin studies resulting in higher estimates than adoption and family designs, indicating the possible importance of the non-additive genetic effect (Vukasović & Bratko, 2015; for twin studies effect sizes see also Polderman et al., 2015; for family studies effect sizes see also Bratko & Marušić, 1997; Bratko et al., 2014). The environmental effect that contributes to individual differences in personality was also substantial, and non-shared by the individuals living in the same environment. Although the genetic effect in a personality domain is substantial, the molecular genetic approach was largely unsuccessful in identifying specific genes responsible for such an effect (Turkheimer et al., 2014), with only a few significant findings with much lower effect sizes (e.g., De Moor et al., 2012; Nagel et al., 2018; van den Berg, 2016).

Many other relevant human phenotypes have also been extensively studied from the behavioral-genetic perspective, but there are still some "blind spots" in the literature. To our knowledge, there has not yet been a study focusing on the relative genetic and environmental contributions to the individual differences in basic psychological needs as operationalized by the SDT. If we look at SDT for some insight on the etiology of basic psychological needs, Ryan and Deci (2008) state that needs for autonomy, competence, and relatedness are universal, and their satisfaction is a key nutriment for psychological well-being and growth, just as the satisfaction of physiological needs is essential for physiological well-being and growth. Consequently, only limited insight about potential sources of individual differences in psychological needs satisfaction comes from its theoretically related variables like well-being (Nes & Røysamb, 2015), or from the analysis of autonomy as a facet of psychological well-being (Ryff & Keyes, 1995). Two studies found significant genetic contributions to individual differences in the facet autonomy, with the best fitting model being AE (additive genetic and non-shared environmental), and the additive genetic estimates accounting for approximately 40% of individual differences in autonomy for both the Italian (Gigantesco et al., 2011) and the USA twin sample (Archontaki et al., 2013).

1.4. The present study

The present study had three aims. The first aim was to explore phenotypical associations between basic psychological needs and the Five-Factor Model of personality traits. We hypothesized that (i) all three basic psychological needs would have a significant negative correlation with neuroticism, and a significant positive correlation with extraversion; (ii) additionally, need for competence would have a significant positive correlation with conscientiousness; and (iii) needs for autonomy and relatedness would have a significant positive correlation with agreeableness.

Our second aim was to use a twin study design and fill the existing gap in the literature on the etiology of individual differences in basic psychological needs, operationalized by the SDT. Since basic psychological needs theoretically represent an innate human universal and, as well as personality traits, may be considered a construct of *basic tendencies* in the McCrae and Costa (2008) *meta*-theoretical framework, we hypothesized that the needs for autonomy, competence, and relatedness would be heritable. Although the *meta*-analysis by Polderman et al. (2015) indicates that many human phenotypes are heritable with an average estimate of 0.49, the unstudied heritability estimates for phenotypes within behavioral-genetic research cannot be assumed and automatically extrapolated from that finding. Due to the lack of empirical findings for this specific phenotype, we turn to estimates of heritability for autonomy, as a facet of psychological well-being, $h^2 \approx$

40% (Archontaki, et al., 2013; Gigantesco, et al., 2011), and to personality traits $h^2 \approx 40\%$ (Vukasovic & Bratko, 2015) as approximations, and we hypothesized that the estimate of genetic contributions to individual differences in basic psychological needs will be in line with them. However, since SDT explicitly states that needs are not as stable as traits because they depend on changes in the environment (Ryan & Deci, 2008), an alternative hypothesis would be that their heritability will be negligible or substantially lower.

Our third aim was to examine the genetic and environmental overlap between needs and traits. We hypothesized that: (i) all three basic psychological needs would share a common genetic and environmental variance with neuroticism and extraversion; (ii) the need for competence would share a common genetic and environmental variance with conscientiousness; and (iii) needs for autonomy and relatedness would share a common genetic and environmental variance with agreeableness.

2. Materials and methods

2.1. Measures

2.1.1. Zygosity questionnaire

Zygosity was determined by an 11-item questionnaire evaluating physical similarities and twin confusion by parents, other family members, teachers, casual friends, and strangers. This questionnaire was used in previous studies on twins (e.g., Bratko et al., 2012). The use of questionnaires for zygosity determination has been shown to be accurate in a number of studies on different populations (e.g., Lenau et al., 2017; Song et al., 2010).

2.1.2. Basic psychological needs

Basic Psychological Need Satisfaction Scale (Deci & Ryan, 2000; Gagné, 2003) focuses on general need satisfaction in one's life. This 21-item scale assesses the degree of satisfaction of the needs for autonomy, competence, and relatedness. Self-reported answers were given on a 7-point Likert scale (1 = "Not true at all" to 7 = "Very true"). Three scale scores were formed as sums of respected items, with a higher score indicating a higher degree of need satisfaction. Following current directions in reliability estimates (McNeish, 2018; Revelle & Zinbarg, 2009), we report Revelle's omega total coefficients, which were 0.72, 0.76, and 0.84 for autonomy, competence, and relatedness, respectively.

2.1.3. Personality traits

Personality traits were assessed by NEO-Five Factor Inventory (NEO-FFI; Costa & McCrae, 1989, 1992). This 60-item questionnaire measures Five-Factor Model personality traits using 12-item scales for neuroticism (N), extraversion (E), openness (O), agreeableness (A), and conscientiousness (C). Revelle's omega total coefficients were 0.84, 0.79, 0.61, 0.71, and 0.85, respectively. These reliabilities are in line with those obtained in previous studies (e.g., Bratko et al., 2012).

2.2. Participants and procedure

All twin pairs born between 1985 and 1992 in the Zagreb county area were identified in the register of citizens. They were contacted and asked to participate in the Croatian research twin project. From 2005 contacted individuals, 732 (36.5%) returned filled-in questionnaires, and a sample including 334 twin pairs, with 103 monozygotic (MZ) and 231 dizygotic (DZ) twin pairs, was included in this study. There were 85 male pairs, 136 female pairs, and 113 opposite-sex pairs in our sample, with an average age of 18.63 (SD = 2.31, range: 15–22). In terms of education, the participants in our sample were either still in high school (40%) or finished high school (55%).

2.3. Analyses

Descriptive statistics, phenotypic correlations, and regression analyses were calculated in SPSS 26.0 (IBM Corp., 2019). We used the Gpower 3.1 (Faul et al., 2009) program to perform a power analysis for the bivariate correlation coefficients and regression models, and to estimate the required sample size. The expected effect size was estimated to be medium ($r = 0.30$; $f^2 = 0.15$), in line with Cohen's (1992) effect size classification. With a Type-1 error rate of 0.05 and the desired statistical power of 0.80, the required sample size was estimated as $N = 67$ for bivariate correlations, and $N = 92$ for linear multiple regression with five predictors. Since our final sample size of 668 individuals (334 twin pairs) exceeds the minimum required for achieving satisfactory statistical power, we believe our results on the phenotype level should be considered valid and robust. The missing data was handled with series mean option within SPSS, for participants that had<10% of missing data. Correlation and regression analyses were performed in order to examine the phenotypical associations between basic psychological needs and personality traits. With correlation analyses, we examined the bivariate associations between each personality trait and each need, while with regression analyses we examined the association between all personality traits and each need, controlling for shared variance between personality traits. Since individuals within twin pairs do not represent independent observations, in all phenotypic analyses degrees of freedom used in statistical tests were adjusted based on the number of twin pairs instead of the number of individuals (McGue et al., 1993).

The structural equation model-fitting program Mx (Neale et al., 2003) was used for genetic model-fitting analyses. Before the genetic model-fitting analyses, age and sex were regressed from the scores using an adjustment procedure proposed by McGue & Bouchard (1984). To calculate statistical power for the planned classical twin study design, we performed several steps. Since the results of statistical power simulations are highly dependent on the input parameters, we consulted the relevant *meta*-analyses regarding the expected effect sizes operationalized as parameter estimates in twin studies (Polderman et al., 2015; Vukasović & Bratko, 2015). Based on the literature and evidence-based data, we made an educated guess of the expected parameter estimates. First, we consulted the twin power calculator (Visscher, 2004; Visscher et al., 2008). Based on our input parameters (A = 0.50, C = 0.00, E = 0.50, $N_{MZ} = 250$, $N_{DZ} = 150$, Type-1 error rate = 0.05, required statistical power = 0.80), the power to detect A was estimated at 0.92, with the required number of twin pairs to detect A for the given ratio of MZ/DZ twin pair estimated at $N = 263$. We further consulted power analyses simulations published by Verhulst (2017), which suggested the number of pairs required to detect estimated A for the given ratio of MZ/DZ twin pairs. Finally, we performed power analyses for the planned parameter estimates using the open-source statistical software program *R* and the package *OpenMx*, as suggested by Verhulst (2017). Based on the plotted power graphs for the univariate and bivariate models, to calculate expected effect sizes of additive genetic (A), shared environmental (C), and non-shared environmental (E) estimates, with the statistical power of 0.80 and the MZ/DZ ratio of 0.625, we would need approximately 300 twin pairs. Therefore, after examining the pattern of MZ-DZ twin intraclass correlations, genetic model-fitting analyses were run. For all three needs full ACE and ADE model and more parsimonious AE and CE sub-models were run first, followed by a series of bivariate correlated factors AE models run between each personality trait and each need. Statistical significance was set at $p < .01$.

3. Results

3.1. Phenotypic overlap between needs and traits

Descriptive statistics, MZ-DZ twin intraclass correlations, and phenotypic correlations between the variables in the study are presented in Table 1.

Table 1
Descriptive statistics, twin intraclass correlations[a], and phenotypic correlations[b] for the variables in the study.

	N	*M (SD)*	*r*MZ (95% CI)	*r*DZ (95% CI)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Autonomy	668	5.15 (0.90)	**0.45** (28.-0.59)	**0.23** (0.10-0.34)							
(2) Competence	668	5.01 (0.97)	**0.50** (0.34-0.63)	**0.14** (0.01-0.27)	**0.45**						
(3) Relatedness	668	5.85 (0.86)	**0.53** (0.38-0.65)	**0.19** (0.06-0.31)	**0.49**	**0.34**					
(4) Neuroticism	648	19.97 (8.62)	**0.64** (0.51-0.74)	**0.21** (0.08-0.33)	**-0.51**	**-0.53**	**-0.37**				
(5) Extraversion	648	30.44 (6.67)	**0.52** (0.36-0.65)	0.12 (-0.01-0.25)	**0.28**	**0.30**	**0.48**	**-0.34**			
(6) Openness	648	23.71 (6.27)	**0.66** (0.54-0.76)	**0.25** (0.12-0.37)	-0.03	0.01	**-0.19**	0.06	-0.11		
(7) Agreeableness	648	30.34 (6.15)	**0.50** (0.34-0.63)	**0.27** (0.14-0.39)	**0.27**	**0.18**	**0.39**	**-0.32**	0.06	**-0.16**	
(8) Conscientiousness	648	31.47 (7.44)	**0.49** (0.33–0.63)	**0.27** (0.14-0.39)	**0.21**	**0.46**	**0.21**	**-0.27**	**0.24**	-0.09	**0.26**

Note. All correlations higher than ± 0.15 significant at $p < .01$ with $df = 321$ in bold. *N* = number of participants, *M* = arithmetic mean, *SD* = standard deviation, *r*MZ = MZ twin intraclass correlation, *r*DZ = DZ twin intraclass correlation. [a] intraclass correlation was calculated on scores adjusted for the age and sex main effects; [b] partial correlations were calculated controlling for the age and sex effects

As Table 1 depicts, all three needs were significantly correlated with four personality traits: negatively with neuroticism and positively with extraversion, agreeableness, and conscientiousness. Only relatedness correlated negatively and significantly with openness. Since personality domains, although theoretically orthogonal, empirically correlate significantly (in this study up to $r = -0.34$) we ran three regression analyses with five personality traits predicting each need. Results are presented in Table 2.

Regression analyses indicated that personality traits, when controlling for age and sex effects, explain 29%, 40%, and 37% of the needs for autonomy, competence and relatedness phenotypic variance, respectively. Neuroticism ($\beta = -0.43$, $p < .001$), agreeableness ($\beta = 0.13$, $p = .002$) and extraversion ($\beta = 0.13$, $p = .001$) were significant predictors of the need for autonomy; neuroticism ($\beta = -0.44$, $p < .001$) and conscientiousness ($\beta = 0.35$, $p < .001$) predicted the need for competence; and extraversion ($\beta = 0.40$, $p < .001$), agreeableness ($\beta = 0.31$, $p < .001$) and neuroticism ($\beta = -0.14$, $p = .001$) the need for relatedness.

Table 2
Results of the hierarchical regression analysis of personality traits on basic psychological needs controlling for age and sex.

Predictors	Autonomy		Competence		Relatedness	
	β	95% CI	β	95% CI	β	95% CI
Step 1						
Age	0.07	-0.01 to 0.15	0.04	-0.05 to 0.13	**-0.10**	-0.18 to -0.02
Sex	0.05	-0.03 to 0.13	-0.06	-0.13 to 0.01	0.06	-0.01 to 0.13
	$R = 0.09$, $R_{adj}^2 = 0.01$		$R = 0.07$, $R_{adj}^2 = 0.00$		**$R = 0.12$, $R_{adj}^2 = 0.01$**	
Step 2						
Age	0.05	-0.02 to 0.12	-0.05	-0.11 to 0.02	**-0.08**	-0.15 to -0.02
Sex	**0.16**	0.09 to 0.23	0.03	-0.04 to 0.10	**0.10**	0.03 to 0.16
Neuroticism	**-0.43**	-0.51 to -0.35	**-0.44**	-0.51 to -0.37	**-0.14**	-0.22 to -0.05
Extraversion	**0.13**	0.06 to 0.20	0.08	0.02 to 0.15	**0.40**	0.34 to 0.47
Openness	0.03	-0.04 to 0.10	0.07	0.01 to 0.13	-0.08	-0.15 to -0.02
Agreeableness	**0.13**	0.04 to 0.20	-0.04	-0.11 to 0.03	**0.31**	0.23 to 0.39
Conscientiousness	0.04	-0.03 to 0.11	**0.35**	0.28 to 0.42	-0.01	-0.07 to 0.05
	$R = 0.54$, $R_{adj}^2 = 0.29$		**$R = 0.64$, $R_{adj}^2 = 0.40$**		**$R = 0.62$, $R_{adj}^2 = 0.39$**	
	$\Delta R^2 = 0.29$		**$\Delta R^2 = 0.40$**		**$\Delta R^2 = 0.37$**	

Note. All coefficients significant at $p < .01$ are in bold; β = standardized regression coefficient; *R* = multivariate regression coefficient; R_{adj}^2 = adjusted multivariate regression coefficient of determination; ΔR^2 = change in multivariate regression coefficient of determination.

3.2. Etiology of basic psychological needs and genetic and environmental overlap between needs and traits

All MZ correlations presented in Table 1 were higher than DZ correlations indicating genetic influences and no shared environmental influences. Univariate genetic analyses for basic psychological needs have indicated that models with genetic influences fitted better than models without genetic influences (see Table 3). Since previous studies have indicated that the best-fitting models for personality traits were AE models (see Vukasović & Bratko, 2015, Polderman et al, 2015), a series of bivariate AE models were run. Broad heritability estimates from bivariate models ranged between 44 and 46% for autonomy, 45–47% for competence, and 51–53% for relatedness. Broad heritability estimates for personality were 60% for neuroticism and openness, 57% for agreeableness, 52% for conscientiousness, and 46% for extraversion.

Results of the bivariate analyses are presented in Table 4. In line with our hypotheses, significant genetic and environmental overlap was found between all three basic psychological needs and neuroticism and extraversion. All genetic and environmental correlations for neuroticism were negative, while for extraversion they were all positive. This indicates that genetic and environmental influences contributing to neuroticism contribute also to some extent to the lower satisfaction of all three needs, while genetic and environmental influences contributing to extraversion contribute to some extent to the satisfaction of all three needs. For openness, all genetic and environmental correlations were nonsignificant, which is in line with our hypotheses, except for the genetic correlation between openness and the need for relatedness. This genetic correlation was negative indicating that genetic influences underlying individual differences in openness are associated with genetic influences underlying lower satisfaction of the need for relatedness. We expected that needs for autonomy and relatedness would share a common genetic and environmental variance with agreeableness. Our hypothesis for relatedness was confirmed, whereas for autonomy only the genetic correlation was significant. In addition, we found a significant genetic correlation between agreeableness and the need for competence. We hypothesized that the need for competence would share a common genetic and environmental variance with conscientiousness, which was confirmed by our results. In addition, conscientiousness shared a common genetic and environmental variance with the need for autonomy and a common genetic variance with the need for relatedness. Using heritability estimates and genetic correlations we further calculated bivariate heritability estimates and compared them with the obtained phenotypic correlations. Overlapping genetic influences explained between 64% and 100% of the phenotypic associations between personality traits and needs.

4. Discussion

The main aim of this study was to fill the existing gap in the literature on the etiology of individual differences in basic psychological needs, operationalized by the SDT, and to examine the etiological overlap

Table 3
Results of the univariate genetic analyses for three needs.

Measures	Model	−2LL (*df*)	AIC	χ^2(*df*)	*p*	A	D	C	E
Autonomy	Saturated	4302.746 (658)	2986.746						
	ACE	4305.521 (663)	2979.521	2.78 (5)	0.74	0.43 (0.04-0.56)		0.01 (0.00-0.29)	0.56 (0.44-0.72)
	ADE	4305.528 (663)	2979.528	2.78 (5)	0.74	0.44 (0.00-0.56)	0.00 (0.00-0.53)		0.56 (0.43-0.69)
	AE	4305.528 (664)	2977.528	0.007 (1)	0.94	0.44 (0.31-0.56)			0.56 (0.44-0.69)
	CE	4310.139 (664)	2982.139	4.62 (1)	0.03			0.29 (0.19-0.39)	0.71 (0.61-0.81)
Competence	Saturated	4199.662 (658)	2883.662						
	ACE	4204.366 (663)	2878.366	4.70 (5)	0.45	0.45 (0.30-0.58)		0.00 (0.00-0.13)	0.55 (0.42-0.70)
	ADE	4201.474 (663)	2875.474	1.81 (5)	0.88	0.04 (0.00-0.52)	0.48 (0.00-0.63)		0.48 (0.37-0.64)
	AE	4204.366 (664)	2876.366	0.00 (1)	1.00	0.45 (0.30-0.58)			0.55 (0.42-0.70)
	CE	4214.715 (664)	2886.715	10.35 (1)	0.001			0.24 (0.14-0.34)	0.76 (0.66-0.86)
Relatedness	Saturated	4412.349 (658)	3096.349						
	ACE	4424.581 (663)	3098.581	12.32 (5)	0.03	0.52 (0.31-0.63)		0.00 (0.00-0.12)	0.48 (0.37-0.63)
	ADE	4421.798 (663)	3095.798	9.45 (5)	0.09	13. (0.00-0.58)	0.45 (0.00-0.68)		0.43 (0.32 -0.57)
	AE	4424.581 (664)	3096.581	0.00 (1)	1.00	0.52 (0.37-0.63)			0.48 (0.37-0.63)
	CE	4437.362 (664)	3109.362	12.78 (1)	<0.001			0.27 (0.17-0.37)	0.73 (0.63-0.83)

Note. RMSEA for saturated and full models < 0.001. −2LL = minus twice the Log-likelihood of the data, df = degrees of freedom, AIC = Akaike Information Criterion, χ^2(df) = -2LL (& df) difference between current and previous model, A = additive genetic variance, D = non-additive genetic variance, C = shared environmental variance, E = non-shared environmental variance, 95% confidence intervals shown in parentheses.

Table 4
Results of the bivariate genetic analyses between each personality trait and each need.

Need	−2LL (*df*)	Additive genetic correlations with	Non-shared environmental correlations with	Bivariate heritability/ phenotypic correlation
Autonomy	8638.124 (1308)	**N -0.65 (-0.79 to -0.49)**	**N -0.37 (-0.50 to -0.22)**	-0.33/-0.51 0.19/0.28
	8518.874 (1308)	**E 0.43 (0.20 to 0.64)**	**E 0.17 (0.01 to 0.32)**	-0.03/-0.03 0.26/0.27
	8438.224 (1308)	O -0.05 (-0.25 to 0.15)	O -0.02 (-0.18 to 0.15)	0.14/0.21
	8398.978 (1308)	**A 0.52 (0.33 to 0.71)**	A 0.02 (-0.14 to 0.19)	
	8644.934 (1308)	**C 0.27 (0.05 to 0.48)**	**C 0.16 (0.01 to 0.32)**	
Competence	8519.121 (1308)	**N -0.73 (-0.87 to -0.58)**	**N -0.32 (-0.47 to -0.16)**	-0.38/-0.53 0.20/0.30
	8411.413 (1308)	**E 0.43 (0.20 to 0.64)**	**E 0.20 (0.03 to 0.35)**	0.02/0.01 0.20/0.18
	8338.616 (1308)	O 0.03 (-0.18 to 0.25)	O -0.03 (-0.20 to 0.15)	0.34/0.46
	8325.244 (1308)	**A 0.39 (0.18 to 0.60)**	A -0.03 (-0.21 to 0.15)	
	8424.362 (1308)	**C 0.68 (0.51 to 0.83)**	**C 0.26 (0.10 to 0.41)**	
Relatedness	8846.072 (1308)	**N -0.53 (-0.68 to -0.36)**	**N -0.19 (-0.35 to -0.01)**	-0.30/-0.37 0.32/0.48
	8529.647 (1308)	**E 0.65 (0.48 to 0.81)**	**E 0.32 (0.16 to 0.46)**	-0.16/-0.19 0.29/0.39
	8537.841 (1308)	**O -0.29 (-0.48 to -0.10)**	O -0.05 (-0.22 to 0.12)	0.18/0.21
	8461.885 (1308)	**A 0.53 (0.35 to 0.68)**	**A 0.25 (0.07 to 0.40)**	
	8763.077 (1308)	**C 0.35 (0.14 to 0.54)**	C 0.09 (-0.09 to 0.25)	

Note. Significant genetic and environmental correlations are in bold. −2LL = minus twice the Log-likelihood of the data, df = degrees of freedom, 95% confidence intervals shown in parentheses.

between psychological needs and personality traits.

4.1. Phenotypic overlap between needs and traits

First, we examined the phenotypical associations between basic psychological needs and the Five-Factor Model personality traits. Results confirmed our hypotheses that: (i) all three needs have a significant negative correlation with neuroticism, and a significant positive correlation with extraversion; (ii) the need for competence has a significant positive correlation with conscientiousness; (iii) needs for autonomy and relatedness have a significant positive correlation with agreeableness. Although there were additional need-trait correlations that reached the level of statistical significance, the most consistent finding of need-trait phenotypical overlap was in line with the hypothesis. Obviously, basic psychological needs have a wide correlational network in the personality domain. Personality traits predicted 29%, 40%, and 37% of needs for autonomy, competence, and relatedness variance, respectively. Prediction is, of course, possible in other direction as well, and basic psychological needs, in a linear regression model, predict a significant ($p < .01$) and substantial amount of the four personality traits variance: 35%, 25%, 04%, 16%, and 21% for neuroticism, extraversion, openness, agreeableness, and conscientiousness, respectively. It is noticeable that needs explained the largest amount of variance for neuroticism and extraversion, the only traits associated with all three needs.

It is difficult to draw cause-and-effect conclusions based on correlational data, but we believe that the causal relationship between needs and traits may be bidirectional. Namely, we agree with Prentice et al.'s (2019) conceptualization that personality traits are tools for satisfying all basic psychological needs. However, the relationship between needs and personality traits can also be observed from the perspective of Ryan and Deci (2008), who assume that needs influence personality development, i.e., that needs are nutriments for personality. In the introduction section, we gave some examples of how personality traits can influence needs satisfaction. But just as, for example, conscientiousness can lead to higher satisfaction of the need for competence, the other direction is also plausible. For example, satisfying the need for competence can boost self-confidence and self-efficiency, increase the likelihood of actively re-engaging , or increase motivation, which all, in turn, may lead to achieving success. This long-term process of gaining mastery and effectiveness in the different activities can consequently affect the development of personality traits, i.e., conscientiousness. Thus, we argue that bidirectional causation is the most plausible explanation of needs-traits relationships, which is also a reason why it is important to study their shared etiology.

4.2. Etiology of basic psychological needs

Our second goal was to conduct the first behavioral genetic study of basic psychological needs and determine the extent to which genetic and environmental effects contribute to individual differences in these

phenotypes. We confirmed the hypothesis about the substantial heritability of basic psychological needs. Heritability estimates were 0.44, 0.45, and 0.52 for the autonomy, competence, and relatedness scale, respectively. These estimates are very similar to the average heritability estimates of personality traits. This finding is relevant for SDT because it supports the conceptualization of the basic psychological needs as human universals. Ryan and Deci's (2008) idea that basic psychological needs are more prone to change than personality traits due to their expected dependence on environmental changes relevant to the degree of their satisfaction is not supported by these results, because the environmental contribution to the individual differences is similar in both phenotypes (for *meta*-analysis of the personality heritability estimate see Vukasovic & Bratko, 2015). However, it should be noted that for answering the question about the etiology of stability and change, either of needs or traits, a longitudinal behavioral genetic design would be needed. It is quite possible and probable that temporal changes in the basic psychological needs and related variables, e.g., well-being, are related to the changes in the environment to which individuals are exposed.

4.3. Genetic and environmental overlap between needs and traits

Our third aim was to examine the genetic and environmental overlap between needs and traits. Results confirmed our hypotheses in part that: (i) all three basic psychological needs shared a common genetic and environmental variance with neuroticism and extraversion; additionally, (ii) the need for competence shared a common genetic and environmental variance with conscientiousness, and (iii) needs for autonomy and relatedness shared a common genetic variance with agreeableness, but only the need for relatedness shared a common environmental variance with agreeableness. Our analyses indicated some additional overlap between personality traits and needs, mainly with conscientiousness. Besides the expected overlap with the need for competence, conscientiousness shared common genetic variance with the other two needs and common environmental variance with the need for autonomy. Openness, in line with hypotheses, did not share genetic and environmental variance with personality traits except for common genetic variance with the need for relatedness.

Further, the phenotypic associations between basic psychological needs and personality traits were mainly due to the shared genetic etiology. These findings support the theory of the "generalist genes", originally proposed by Plomin and Kovas (2005) in the cognitive domain, which predicts that genetic factors contribute to the covariation of different phenotypes, while environmental effects are mostly independent. We believe it is possible to generalize this reasoning to the relations between needs and traits as well, meaning that needs and traits have common genetic and largely independent environmental etiology. Although the overlap between non-shared environmental effects was significant for many needs-traits combinations, it is noticeable that for all significant phenotypic correlations, the genetic correlations were substantially higher than environmental correlations. Moreover, the bivariate heritability estimates suggest that a shared genetic etiology contributes strongly to the phenotypic correlation between the basic psychological needs and personality traits.

4.4. Limitations and future directions

Presented research of course has some limitations. Firstly, although twin design is a powerful design for detecting a total genetic and environmental effect, the power for distinguishing the genetic mechanism, i.e., to distinguish between additive *vs.* non-additive effects, is limited given the available sample size. Therefore, the replication of these findings using the family and adoption designs, as well as the extended twin/family design, would be welcomed. Secondly, both basic psychological needs and personality traits were assessed via self-report questionnaires with imperfect psychometrical properties. At least for personality assessment the additional source from peer-rating would improve the assessments and might influence results. Thirdly, since basic psychological needs are inherently dynamic concepts, we feel that using a longitudinal design would be crucially important in future studies in order to understand the bidirectional causal relations between basic psychological needs and traits.

Last but not least, the classical twin design which was used in this study does not take into account the possible role of gene-environment interactions and correlations (see Plomin et al. 1977; Scarr & McCartney, 1983) in explaining the process leading to the phenotypic correlations between traits and needs. We believe that gene-environment correlation may play a particularly important role, either in its passive, active, or evocative form. Passive gene-environment correlation occurs because children receive both environment and genotype from their parents. Active gene-environment correlation occurs when individuals select environments which are correlated with their genetically influenced traits, while evocative gene-environment correlation occurs when genetically influenced traits evoke the environmental responses in other individuals. If the environment to which individuals are exposed correlates with their genetic predispositions, it is quite possible that the shared genetic etiology of two phenotypes actually involves a correlation of environmental influences of one variable (e.g., personality trait) and genetic influences of the other variable (e.g., need). For example, the level of the need for relatedness might, in a motivational cycle, lead to the behavior that satisfies that need (e.g., socializing). That might elicit the exposure to the specific environment (e.g., other people's behavior) which in turn could potentially influence personality trait (e.g., extraversion). Although our study indicates that relationships between basic psychological needs and personality traits exist at both the phenotypic level and at the level of their shared etiology, future work could benefit from direct measurement of both genetic and environmental factors, and perhaps from hypothesis-driven research examining specific gene-environment interactions and correlations.

5. Conclusion

Behavioral genetic analysis indicates that individual differences in basic psychological needs may be explained by additive genetic and non-shared environmental influences. The heritability estimates for autonomy, competence, and relatedness were 0.44, 0.45, and 0.52, respectively. Those indices are very similar to the heritability estimates of personality from twin studies. The genetic effect of the needs substantially overlaps with the genetic effect of personality, and between 64% and 100% of the personality-need phenotypic associations can be explained by the overlapping genetic influences. Therefore, it may be concluded that the etiology of the phenotypic associations between basic psychological needs and personality traits is mainly due to the shared genetic contributions, while the environmental contributions are largely independent.

Author notes:

The reported study was not pre-registered. The data that support the findings of this study are publicly available on Mendeley Data: https://data.mendeley.com/datasets/4fc4342zk3/1.

Funding statement

This research used data from the research project on Croatian twins, which was supported by grants from the University of Zagreb, Croatia, awarded to the first author.

Ethics approval statement

Ethics approval was obtained in line with the protocol for research projects at the Department of Psychology, Faculty of Humanities and Social Sciences, University of Zagreb. All potential participants were informed of research aims and decided to participate voluntary, anonymously, and with no compensation. All participants gave their informed consent for the results to be published on a group level, with no personal information.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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