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Comparing phenotypic, genetic, and environmental associations between personality and loneliness

Colin D. Freilich [a,*], Frank D. Mann [b], Susan C. South [c], Robert F. Krueger [a]

[a] Department of Psychology, University of Minnesota, USA
[b] Department of Family, Population, and Preventative Medicine and Program in Public Health, Stony Brook University, USA
[c] Department of Psychology, Purdue University, West Lafayette, IN, USA

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ABSTRACT

As a strong risk factor for mortality, individual differences in loneliness are of clear public health significance. Four of the Big Five traits have emerged as cross-sectional correlates, but the etiology of these links is unclear, as are relations with more specific personality facets. Thus, we estimated phenotypic, genetic, and environmental associations between loneliness and both broader and narrower personality dimensions. Traits that indexed Negative Emotionality (e.g., Neuroticism, Stress Reactivity, Alienation) and low Positive Emotionality (e.g., low Extraversion, low Well-Being) had the strongest associations with loneliness, though low Conscientiousness, low Agreeableness, and high Aggression were also implicated. These associations were explained by both genetic ($0.30 < |r_g| < 0.80$) and unique environmental ($0.10 < |r_e| < 0.35$) influences, consistent with an etiology of loneliness involving several personality domains.

1. Introduction

Loneliness can be defined as a distressing feeling that accompanies the perception that one's social needs are not being met by one's interpersonal relationships (Hawkley & Cacioppo, 2010). Loneliness is therefore a subjective emotional experience, distinct from being alone, which is often operationalized using self-report measures of social isolation. Loneliness is commonly measured through self-report questionnaires, such as the UCLA Loneliness Scale (Russell et al., 1978). These subjective measures are associated with numerous adverse physical and mental health outcomes, including cognitive decline (Kuiper et al., 2015), internalizing psychopathology (Beutel et al., 2017), and cardiovascular disease (Valtorta et al., 2016). In fact, the impact of loneliness is comparable in magnitude to other well-established risk factors for mortality such as substance abuse, obesity, and low levels of physical activity (Holt-Lunstad et al., 2015).

In recent years, the nature and correlates of loneliness have received increased empirical attention,[1] perhaps in growing recognition of its general public health relevance, and likely further underscored by the COVID-19 pandemic (e.g., Luchetti et al., 2020; Groarke et al., 2020; Killgore et al., 2020). The National Academy of Sciences has emphasized the importance of studying the basic mechanisms of loneliness, particularly in older adult populations, as they often face predisposing factors like living alone, loss of family and friends, sensory impairments, and chronic illness. The Academy's loneliness committee recommended "increased funding of basic research as a key to achieving the goal of developing a more robust evidence base on effective prevention, assessment, and intervention for social isolation and loneliness" (National Academies of Sciences, 2020, pp. 71).

Efforts have been made to understand individual differences in loneliness, and the Five Factor Model (FFM) of personality has emerged as a useful framework for doing so. In particular, Neuroticism and low Extraversion are strong cross-sectional correlates of loneliness across undergraduate (Saklofske & Yackulic, 1989; Stokes, 1985) and older adult samples (Hensley et al., 2012; Long & Martin, 2000). While less robust than associations with Neuroticism and low Extraversion, a recent meta-analysis provided evidence that low Agreeableness and low Conscientiousness were moderately associated with loneliness (Buecker et al., 2020). The fifth trait domain, Openness, was only weakly negatively associated with loneliness. The authors did not consider personality domains other than the Big Five, but noted, "the relation between loneliness and personality facets may yield a more fine-grained portrayal of how personality and loneliness are interwoven" (Buecker et al., 2020, pp. 34).

* Corresponding author.
E-mail address: freil016@umn.edu (C.D. Freilich).

[1] As of this writing, a simple keyword search in PubMed for "loneliness" yields 2,277 results in the year 2021, compared to 879 in 2019, and 198 in 2009.

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Like personality traits, there are genetically influenced individual differences in how often people feel lonely. Twin and family studies can be used to understand the etiology of those differences. The heritability of loneliness, or percentage of variance due to genetic differences between people, is estimated to be around 30–55 %; non-shared, rather than common environmental factors, account for the remaining variance (Schermer & Martin, 2019; Distel et al., 2010; McGuire & Clifford, 2000). These estimates are similar in magnitude to those of each of the Big Five traits (Vukasović & Bratko, 2015).

The extent to which overlapping genetic and environmental factors contribute to the covariation between personality and loneliness offers a window into their co-occurrence, and, therefore, may inform future prevention and intervention efforts. For instance, if we know that the genetic influences between Neuroticism and loneliness are largely overlapping, it may suggest different prevention efforts (e.g., individual therapy that focuses on insight building) than if the genetic influences are not associated but environmental influences are correlated (e.g., behavioral interventions). A genetic correlation (r_g) estimates the standardized degree of association between the latent genetic variance components underlying two phenotypes while a unique environmental correlation (r_e) estimates the standardized degree of association between the latent unique environmental variance components underlying two phenotypes. Put differently, genetic correlations measure the degree to which the genetic influences on two traits are correlated, while environmental correlations do the same for environmental influences.

Significant unique environmental correlations would be consistent with personality underlying the development of loneliness, net of genetic confounding; however, with only cross-sectional observational data, it is difficult to infer the direction of causality. Therefore, loneliness underlying personality change would also be plausible, as would exogenous environmental factors underlying changes in both. Previous evidence suggests that the longitudinal influence of Neuroticism on residual change in loneliness is stronger (e.g., $\beta = 0.21$) than that of loneliness on residual change in Neuroticism (e.g., $\beta = 0.09$) though statistically significant relations have been observed in both directions (Abdellaoui et al., 2019a; Mund & Neyer, 2016).

To our knowledge, there have been only three investigations into the genetic architecture linking personality and loneliness. Abdellaoui et al. (2019a) argue that the association between loneliness and Neuroticism is largely genetic in nature ($r_g = 0.71$) and that this genetic link drives the associations between other personality traits with loneliness (e.g., Conscientiousness was not significantly associated with loneliness after covariation with Neuroticism was removed). They also found evidence consistent with a reciprocal causal relationship between Neuroticism and loneliness, based on within monozygotic twin pair differences in one phenotype predicting the other phenotype (though Neuroticism differences were more predictive of loneliness than loneliness differences were of Neuroticism). Schermer and Martin (2019) demonstrated a similarly strong genetic correlation between Neuroticism and loneliness ($r_g = 0.81$), and they also examined genetic and environmental correlations with the rest of the Big Five. Significant genetic correlations were observed with low Extraversion ($r_g = -0.62$), low Conscientiousness ($r_g = -0.44$), low Agreeableness ($r_g = -0.25$), and Openness ($r_g = 0.16$). In addition, they observed significant environmental correlations with Neuroticism ($r_e = 0.48$), low Extraversion ($r_e = -0.23$), low Conscientiousness ($r_e = -0.15$), and low Agreeableness ($r_e = -0.14$), but not Openness ($r_e = 0.06$). Finally, Abdellaoui et al. (2019b) used genome-wide association techniques rather than behavioral genetic techniques. This approach analyzes genomic similarity at the level of identified single nucleotide polymorphisms (SNPs) among unrelated individuals, so only the additive genetic effects explained by the measured and imputed SNPs are accounted for in the analyses (Friedman et al., 2021). They estimated genetic correlations between loneliness and Neuroticism ($r_g = 0.69$), low Extraversion ($r_g = -0.17$), low Conscientiousness ($r_g = -0.22$), low Agreeableness ($r_g = -0.42$), and Openness ($r_g = 0.03$). Only a small number of significant SNPs for loneliness have been discovered (Day et al., 2018), and, while the pattern of results is largely similar across techniques, this may account for the discrepancies in estimated magnitudes between biometric and molecular genetic studies.

Overall, genetic correlations appear largely consistent across studies when estimated using biometric, rather than molecular approaches, but this finding requires further replication. Neuroticism and low Extraversion display the strongest phenotypic and genetic correlations with loneliness, with low Conscientiousness and low Agreeableness also displaying significant, but more moderate levels of genetic overlap. With only one prior study (Schermer & Martin, 2019), the environmental correlations between personality and loneliness require replication, though the discordant twin pair evidence from Abdellaoui et al. (2019a) is consistent with overlap in the unique environment between Neuroticism and loneliness. Therefore, our first goal was to clarify and help resolve the discrepancies in previous literature, especially regarding the role of environmentally mediated linkages with traits other than Neuroticism. We aimed to achieve this goal by providing estimates of the genetic and environmental contributions to the covariation between personality and loneliness in a nationwide adult twin sample.

In addition, a related goal was to estimate linkages between loneliness and more narrow facets of personality, aiming for a more fine-grained understanding of the specific traits that may underlie the development of loneliness. The Multidimensional Personality Questionnaire (MPQ) indexes domains of Negative Emotionality, Positive Emotionality, and Constraint (Tellegen & Waller, 2008), which have strong theoretical and empirically demonstrated ties to Neuroticism, Extraversion, and Conscientiousness, respectively (Church, 1994). In addition, the MPQ measures ten specific trait dimensions underlying the three broad domains, making it a valuable tool for understanding narrow facets of personality. Indeed, Schermer and Martin (2019) conclude "future research may expand on the relationships found in the present study by examining … more narrow facets of personality" (p. 136). In summary, the present study adds to existing literature by providing additional estimates of the genetic and environmental correlations between loneliness and the Big Five personality traits and extends the findings to more narrow dimensions of personality measured by the MPQ.

2. Method

2.1. Participants

The sample includes adult twins who participated in the National Survey of Midlife Development in the United States (MIDUS; Brim et al., 2004). MIDUS investigates the role of behavioral, psychological, and social factors in understanding age-related differences in physical and mental health. The first wave of data collection took place in 1995–1996 (MIDUS 1), and a longitudinal follow-up on the original participants was conducted in in 2004–2006 (MIDUS 2). Data are extracted for the present study from this second wave of collection. Data were collected on 1,914 twins in MIDUS 1 and 1,484 twins in MIDUS 2. The MPQ and the loneliness items were not collected in MIDUS 1. Because the current study is interested in genetic and environmental correlations among loneliness and personality variables, we only use data from MIDUS 2 intact twin pairs who completed both assessments. 808 had sufficient data on the requisite measures for themselves and their co-twin. Thus, the final sample size was 404 twin pairs, consisting of 168 (72 male, 96 female) monozygotic (MZ), 142 same-sex (46 male, 96 female) dizygotic (DZ), and 94 opposite-sex DZ pairs.

The age of participants spanned 34–82 years (mean = 54.52; 59 % female). 95 % of participants identified their main racial origins as White, 2 % as African American, 1 % as Native American, <1% as Native Hawaiian or Pacific Islander, and 2 % as other or unsure. While racial diversity was relatively limited in the sample, there was considerable variability in education level (~56 % without a college degree, ~30 % with undergraduate degree, ~13 % with graduate degree). Additional

information on data collection and recruitment of participants can be found elsewhere (e.g., Brim et al., 2004; Ryff & Krueger, 2018).

2.2. Measures

2.2.1. Loneliness

Loneliness was measured by asking participants to indicate "During the past 30 days, how much of the time did you feel [blank]". There were three items: "lonely", "close to others", and "like you belong". Items were rated on a 5-point scale (1 = None of the time, 2 = A little of the time, 3 = Some of the time, 4 = Most of the time, 5 = All of the time), and the second and third items were reverse coded so that higher average scores reflected higher levels of loneliness. Answers to these three questions were averaged to estimate self-reported loneliness (α = 0.74, ω_T = 0.77). Though not a formal loneliness scale, items resemble those of the often-used UCLA Loneliness Scale and De Jong Gierveld Loneliness Scale. For instance, the UCLA scale asks how often participants feel as though "(they) feel completely alone", "(are) no longer close to anyone", and "People are around me but not with me" (Russell et al., 1978). Further, the 20-item UCLA scale has been adapted to a 3-item short form with evidence for strong convergent and discriminant validity (Hughes et al., 2004). In addition, the single self-report "lonely" item has been used as an index of loneliness in MIDUS (Nersesian et al., 2018), as has the same three item sum score (Freilich et al., 2022), and the three items are moderately to highly correlated (0.37 < r < 0.71, *ps* < 0.001).

Because of the wide age range in the sample, it is unclear if the loneliness items had comparable meanings across participants varying in age. Therefore, we conducted measurement invariance analyses across age groups. We specified a two-group confirmatory factor analysis model where members of one group were defined as those younger than 54 years old (N = 405) and members of the second group were 54 years or older (N = 403). Each of the three loneliness items loaded onto the single latent factor, and, because the indicators were categorical, the model was estimated using diagonally weighted least squares (DWLS). Results of the configural model (which allows unique models to be estimated across groups), the metric model (which constrains item loadings to equality across groups), and the scalar model (which constrains item loadings and thresholds to equality across groups) are summarized in Supplemental Table S1. Crucially, the parameter constraints did not lead to significant loss of model fit, suggesting the measure of loneliness is invariant across age groups. Also of note, this same measure has been shown to be invariant across race (Freilich et al., 2022).

2.2.2. Midlife development Inventory (MIDI)

The Big Five personality traits were measured using the Midlife Development Inventory (MIDI) (Lachman & Weaver, 1997). Participants were asked to indicate "how well each of the following [adjectives] describes you." Five adjectives were used to measure Extraversion (α = 0.76, ω_T = 0.79), Agreeableness (α = 0.82, ω_T = 0.85), and Conscientiousness (α = 0.63, ω_T = 0.72). Four adjectives were used to measure Neuroticism (α = 0.74, ω_T = 0.83), and seven adjectives were used to measure Openness (α = 0.76, ω_T = 0.85). The MIDI includes a 6th trait domain, Agency, which indexes individuality, forcefulness, and control and was measured using five adjectives (α = 0.78, ω_T = 0.82).. Items were rated on a 4-point scale (4 = A lot, 3 = Some, 2 = A little, 1 = Not at all), and were reverse coded when necessary so that higher average scores reflected higher levels of the trait.

2.2.3. Multidimensional personality Questionnaire (MPQ)

Personality traits were also assessed using a shortened version of the Multidimensional Personality Questionnaire (MPQ; Patrick et al., 2002; Tellegen & Waller, 2008). Participants were asked to rate how well they are described by each of 35 statements selected to assess 10 lower-order traits subsumed by three higher-order traits (Positive Emotionality, Negative Emotionality, and Constraint). Items were rated on a 4-point scale (1 = True of you, 2 = Somewhat true, 3 = Somewhat false, or 4 = False), and were reverse coded when necessary so that higher values reflected higher standing on the trait.

The traits subsumed by Positive Emotionality are Well-Being, Social Potency, Social Closeness, and Achievement. Well-Being was assessed by three items (α = 0.73, ω_T = 0.70). Social Potency (α = 0.66, ω_T = 0.79), Social Closeness (α = 0.68, ω_T = 0.77), and Achievement (α = 0.66, ω_T = 0.71) were each assessed by four items. Positive Emotionality is conceptually linked with Extraversion (Church, 1994).

The traits subsumed by Negative Emotionality are Stress Reactivity, Aggression, and Alienation. Stress Reactivity (α = 0.75, ω_T = 0.72) and Alienation (α = 0.66, ω_T = 0.63) were assessed by three items. Aggression was assessed by four items (α = 0.64, ω_T = 0.81). Negative Emotionality is conceptually linked with Neuroticism and low Agreeableness. Specifically, Stress Reactivity is roughly equivalent to Neuroticism and Aggression is a strong marker of the negative pole of Agreeableness (Church, 1994).

The traits subsumed by Constraint are Control, Traditionalism, and Harm Avoidance. Control (α = 0.61, ω_T = 0.59) and Traditionalism (α = 0.61, ω_T = 0.58) were each assessed by three items. Harm Avoidance was assessed by four items (α = 0.57, ω_T = 0.63). Constraint is conceptually linked with Conscientiousness and low Openness. Specifically, Control is strongly associated with Conscientiousness and Traditionalism is moderately and negatively associated with specific aspects of Openness (Church, 1994).

For some of these measures, Cronbach's alpha fell below conventional standards for adequate internal consistency (α < 0.70), but many have argued that McDonald's omega is a better measure of internal consistency (McDonald, 1999; Revelle & Zinbarg, 2008; Sijtsma, 2009; Zinbarg et al., 2005). Perhaps more importantly, modest internal consistencies are not only expected but preferred when measuring a broad content space with a relatively brief questionnaire (Boyle, 1991; Kline, 1979), as high internal consistency may indicate that the brief measure is redundant or too highly focused and, thus, fails to adequately cover the full breadth of the construct (Kline, 1986, pp. 118).

2.3. Data preparation

Prior to conducting analyses, data were inspected for meeting the statistical assumption of normality. Visual inspection of the scale histograms and density plots suggested that Stress Reactivity, Aggression, and Alienation all had a positive skew, while Agreeableness, Extraversion, and Conscientiousness had a negative skew. Similar to previous personality-genetics research and because traditional ACE models may provide decreased accuracy for estimating variance components of non-normally distributed variables (Arbet et al., 2020), skewed variables were transformed with a rank-based transformation. For positively skewed variables, a Blom transformation was applied (Blom, 1958; Wright et al., 2017). For negatively skewed variables, a cube-root transformation was applied (Distel et al., 2011). As recommended for variables subjected to biometric analyses, all variables were then regressed on sex, the linear and quadratic effects of age, and the age-sex interaction; this removes any similarity between twins that is due to being the same age and sex, and thus serves to avoid overestimating twin intraclass correlations (McGue & Bouchard, 1984). The standardized residuals of these regressions were then used in the following analyses.

2.4. Statistical analysis

First, we estimated successive univariate ACE, ADE, and AE models that decompose variance in personality traits and loneliness into additive genetic (A), non-additive genetic (D), common environmental (C), and non-shared environmental components (E). Personality traits and loneliness often show little to no common environmental components when examining broad, average estimates of variance (Wright et al.,

2017; Boomsma et al., 2006), suggesting that a more parsimonious model that excludes a common environmental component (C) might fit the data well. However, evidence from extended family designs, which leverage additional data from non-twin family members when considering genetic and environmental effects, has suggested that common environmental effects are greater than zero (e.g., Neuroticism C = 0.13; Boomsma et al., 2018). We used the Akaike Information Criteria (AIC) to compare each ACE, ADE, and simpler AE models for each trait, and the model with the lowest AIC was determined to best fit the observed data. Using methods described by Verhulst (2017), with 168 MZ and 236 DZ twins, we can detect a heritability of 0.50 with power of 0.930, given limited common environmental effects (i.e., C = 0.01).

After modelling the appropriate univariate decompositions, we then estimated bivariate ACE, ADE, and AE models, specifically "Cholesky Decompositions" of the covariance between loneliness and personality traits (Loehlin, 1996). For each trait and loneliness, the best fitting of these three models was then transformed into a "Correlated Factors" model for ease of interpretation of genetic and environmental contributions to the phenotypic covariance (Loehlin, 1996).

Univariate and bivariate models were estimated in OpenMx (Boker et al., 2021), modifying sample scripts by Dr. Hermine Maes (https://hermine-maes.squarespace.com/). Given expected univariate parameters[2] and our sample size, we can detect a genetic correlation of 0.6 with power of 0.853 (Verhulst, 2017). Data from the MIDUS study is available to the public through the MIDUS Colectica portal (https://midus.colectica.org/) and the base data, code, and full results for this study are available at: https://osf.io/h5c7r/.

3. Results

3.1. Phenotypic analyses

Correlations between loneliness, the Big Five, and the MPQ traits are presented in Table 1; correlations are provided for variables both before and after transformation and regression procedures. Each of the Big Five traits had moderate to strong phenotypic correlations with loneliness ($0.23 \leq |r| \leq 0.40$). In addition, each of the MPQ traits apart from Control (r = -0.06), Traditionalism (r = 0.01), and Harm Avoidance (r = -0.03) had moderate to strong correlations with loneliness ($0.19 \leq |r| \leq 0.42$). Traits indexing Negative Emotionality (e.g., Neuroticism r = 0.40; Stress Reactivity r = 0.42; Alienation r = 0.30) and low Positive Emotionality (e.g., Extraversion r = -0.34; Well-Being r = -0.39; Social Closeness r = -0.28), had the largest correlations with loneliness.

Because items assessing personality often use similar language as items assessing loneliness, we calculated bivariate Spearman rank-based correlations (ρ) between loneliness and the individual items (untransformed) that are summed to index the personality traits. If similar language was used to index both constructs, the observed phenotypic correlations may reflect artifactual criterion contamination rather than a substantive association between distinguishable constructs. MIDI item-level correlations are summarized in Supplemental Table S2 and MPQ item-level correlations are summarized in Supplemental Table S3. For instance, correlations between loneliness and the Neuroticism adjectives were as follows: "moody" $\rho = 0.34$, "worrying" $\rho = 0.25$, "nervous" $\rho = 0.25$, and "calm" $\rho = -0.34$ (item is reverse scored to index Neuroticism). These item correlations within a given trait were similarly consistent across different dimensions of personality, indicating that individual "contaminated" items were not driving the observed correlations between loneliness and broader dimensions of personality. In fact, the differences between each trait's set of item-level correlations (ρ) were within 0.15 of the domain-level correlations with loneliness, except for Agency (e.g., "self-confident" $\rho = -0.40$; "outspoken" $\rho = -0.06$). Because

[2] We estimated a heritability for both variables of 0.50, with limited common environmental effects (i.e., C = 0.01).

Table 1
Correlations among Loneliness, Big Five, and MPQ Traits.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Age	−0.16*	−0.20*	0.12*	0.13*	0.03	−0.02	0.12*	−0.08*	−0.02	0.04	−0.13*	−0.14*	−0.09*	0.07	0.13*	0.16*	0.03
Sex (1 = Male, 2 = Female)	−0.02	0.06	0.26*	0.05	−0.03	0.09*	−0.04	−0.15*	−0.06	0.14*	−0.03	−0.13*	−0.03	0.02	0.07	0.24*	−0.12*
1. Loneliness		0.40*	−0.27*	−0.37*	−0.24*	−0.28*	−0.41*	−0.18*	−0.18*	−0.28*	0.42*	0.25*	0.32*	−0.09*	−0.01	−0.05	−0.21*
2. Neuroticism	0.39*		−0.10*	−0.18*	−0.22*	−0.17*	−0.36*	−0.13*	−0.20*	−0.15*	0.66*	0.34*	0.38*	−0.02	0.00	−0.01	−0.09*
3. Agreeableness	−0.26*	−0.10*		0.47*	0.32*	0.28*	0.25*	0.06	0.17*	0.40*	−0.15*	−0.24*	−0.04	0.23*	0.15*	0.17*	0.07
4. Extraversion	−0.36*	−0.16*	0.46*		0.50*	0.29*	0.53*	0.42*	0.34*	0.45*	−0.23*	−0.11*	−0.16*	0.09*	0.01	−0.04	0.52*
5. Openness	−0.24*	−0.22*	0.34*	0.50*		0.41*	0.50*	0.43*	0.48*	0.14*	−0.21*	−0.11*	−0.17*	0.15*	−0.21*	−0.21*	0.49*
6. Conscientiousness	−0.29*	−0.19*	0.28*	0.30*	0.41*		0.24*	0.16*	0.40*	0.09*	−0.24*	−0.26*	−0.27*	0.36*	0.02	0.05	0.29*
7. Well-Being	−0.40*	−0.35*	0.25*	0.52*	0.51*	0.25*		0.36*	0.46*	0.28*	−0.30*	−0.10*	−0.17*	0.15*	−0.03	−0.12*	0.38*
8. Social Potency	−0.21*	−0.14*	0.12*	0.45*	0.44*	0.18*	0.38*		0.39*	0.17*	−0.11*	0.03	−0.11*	−0.03	−0.10*	−0.18*	0.56*
9. Achievement	−0.19*	−0.20*	0.20*	0.35*	0.48*	0.40*	0.47*	0.39*		0.12*	−0.14*	−0.08*	−0.06	0.21*	−0.02	−0.17*	0.37*
10. Social Closeness	−0.28*	−0.15*	0.38*	0.45*	0.14*	0.08	0.29*	0.20*	0.13*		−0.18*	−0.14*	−0.15*	0.09*	0.13*	0.13*	0.10*
11. Stress Reactivity	0.40*	0.66*	−0.13*	−0.21*	−0.21*	−0.25*	−0.29*	−0.12*	−0.14*	−0.18*		0.46*	0.47*	−0.04	0.06	−0.12*	−0.09*
12. Aggression	0.23*	0.35*	−0.21*	−0.11*	−0.12*	−0.25*	−0.11*	−0.01	−0.12*	−0.12*	0.45*		0.44*	−0.07	−0.03	−0.18*	0.13*
13. Alienation	0.31*	0.38*	−0.03	−0.15*	−0.18*	−0.27*	−0.18*	−0.12*	−0.07	−0.14*	0.47*	0.42*		−0.01	0.08*	−0.05	−0.07
14. Control	−0.08*	0.00	0.22*	0.08*	0.15*	0.37*	0.14*	−0.02	0.21*	0.09*	−0.03	−0.07	−0.01		0.14*	0.16*	0.01
15. Traditionalism	0.01	0.02	0.11*	−0.01	−0.21*	0.02	−0.04	−0.08	−0.01	0.11*	0.08*	−0.01	0.11*	0.13*		0.23*	−0.06
16. Harm Avoidance	−0.02	0.00	0.09*	−0.07	−0.21*	0.04	−0.14*	−0.13*	−0.15*	0.09*	−0.09*	−0.13*	−0.02	0.15*	0.20*		−0.16*
17. Agency	−0.21*	−0.08*	0.11*	0.53*	0.48*	0.30*	0.38*	0.55*	0.37*	0.12*	−0.09*	0.11*	−0.08	0.01	−0.06	−0.14*	

Note. * $p < .01$. Correlations are reported above the diagonal before transformation procedures and regressions that control for age and sex and below the diagonal after such procedures. $n \geq 972$ pairwise, inclusive of participants without a twin in the dataset. Later tables include only the approximately 405 twin pairs. These estimates do not adjust for dependence or clustering.

of these consistencies across items and because scales were brief (i.e., the majority of traits were indexed by 3 or 4 items), we proceeded using all available items.[3]

Semi-partial correlations were calculated to estimate the association between each personality trait with loneliness net of covariation with the other traits in the model (e.g., association between Neuroticism and Loneliness net of Agreeableness, Extraversion, Openness, Conscientiousness, and Agency, but not the MPQ traits). Semi-partial correlations with loneliness were significant for Neuroticism (r = 0.33), low Extraversion (r = -0.15), low Conscientiousness (r = -0.11), Stress Reactivity (r = 0.21), Alienation (r = 0.11), low Well-Being (r = -0.20), and low Social Closeness (r = -0.12).

3.2. Univariate biometric analyses

As a first step, the intraclass correlation (ICC) between twin pairs was calculated, separately for MZ twins and DZ twins, for loneliness and each personality trait. The MZ twin pair correlation was always higher than the DZ correlation, suggesting additive genetic influences. ACE, ADE, and AE models were estimated for loneliness and each personality trait. The fit statistics and parameter estimates for the univariate models that estimate genetic and environmental contributions to variance are displayed in Table 2. The reduced AE model fit the data best for loneliness and for 14 of the 16 personality traits. In each of these cases, the greatest proportion of variance was accounted for by unique environmental effects (E), with the remaining variance accounted for by additive genetic effects (A). The full ACE model fit the data best for the trait Traditionalism. The ADE model fit the data best for the trait Neuroticism. In Supplemental Table S4, ICCs are stratified by sex. Because only minor differences were observed across sex (e.g., ICCs between DZ male pairs, DZ female pairs, and opposite-sex DZ pairs), sex limitation models were not considered.

3.3. Bivariate biometric analyses

Next, bivariate "Cholesky Decompositions" of the covariance between each personality trait with loneliness were estimated. Three models were again estimated for each pair: an ACE model, an ADE model, and a reduced AE model. In all cases the reduced AE model had the best fit to the data, as indicated by the lower AIC value, so only results from AE models are reported. These models allow us to test if genetic and non-shared environmental components of personality traits co-varied with those of loneliness. The genetic and non-shared environmental correlations between each of the Big Five and MPQ personality traits and loneliness are reported in Table 3, along with the phenotypic and semi-partial correlations for completeness.

Significant genetic correlations with loneliness were observed for Neuroticism, Stress Reactivity, Aggression, Alienation, low Extraversion, low Well-Being, low Social Closeness, low Social Potency, low Achievement, low Agency, low Agreeableness, low Openness, and low Conscientiousness. Significant non-shared environmental correlations with loneliness were observed for Neuroticism, Stress Reactivity, Aggression, low Extraversion, low Well-Being, low Social Potency, low Achievement, low Agency, low Openness, and low Conscientiousness.

In addition, sensitivity analyses were conducted to estimate model parameters without transformation and regression procedures and after excluding opposite-sex DZ twin pairs.[4] First, in Supplemental Table S5, univariate models were run on a selection of variables before they were transformed to account for skewness and before sex, the linear and quadratic effects of age, and the age-sex interaction were regressed out. In Supplemental Table S6, the phenotypic, semi-partial, genetic, and unique environmental correlations for these variables (again untransformed and before regression) with loneliness are estimated. These models suggest that results are largely robust to data transformations. Similarly, because inclusion of opposite-sex twin pairs may violate the equal environments assumption of the classical twin design, univariate results without these participants (i.e., with only MZ twins and same-sex DZ twins) are shown in Supplemental Table S7, and bivariate results are in Supplemental Table S8. Again, these models suggest that the inclusion opposite-sex DZ twins did not substantively bias results.

4. Discussion

Consistent with previous studies, we observed small to moderate phenotypic associations between loneliness and FFM domains of personality including Neuroticism, low Extraversion, and low Conscientiousness (Buecker et al., 2020; Schermer & Martin, 2019; Stokes, 1985). Further, we observed several moderate phenotypic associations with additional personality dimensions from the MPQ, such as Social Closeness and Alienation, providing a more fine-grained understanding of the trait predictors of loneliness. Semi-partial correlations indicate that some, but not all, of these traits explain additional variance in loneliness net of their covariation with the other domains of personality. Neuroticism displayed the strongest semi-partial correlation with loneliness. Notably, some traits indicative of low Positive Emotionality and low Conscientiousness remained significant in semi-partial correlations, in contrast to the results from Abdellaoui et al. (2019a), suggesting traits beyond Neuroticism may be relevant to understanding individual differences in loneliness.

We replicated prior work that has found moderate heritability of major domains of personality. Loneliness had a heritability of 28 % and a nonshared environmental variance of 72 %. The only construct to show evidence of nonadditive genetic effects was Neuroticism, and the only construct to show evidence of common family effects was Traditionalism (C = 0.21). With these two exceptions, the heritability of personality traits was between 27 % and 46 %. These estimates are similar to, but slightly lower than those observed elsewhere (e.g., Schermer & Martin, 2019; Distel et al., 2010; Vukasović & Bratko, 2015). There are multiple possible explanations for this, including the somewhat lower reliability of some of the included scales (measurement error is subsumed under the unique environmental E component). Moreover, the proportion of phenotypic variance explained by additive genetic factors (i.e., heritability) is not a fixed parameter, rather, heritability can change across cohorts, populations, stages of lifespan development, and different environmental exposures.

We also replicated previous evidence of a non-zero genetic overlap between loneliness and multiple domains of personality. We hypothesized that genetic correlations would be closer to estimates from prior studies using behavioral, rather than molecular genetic techniques, but comparisons were inconclusive. Supplemental Table S9 summarizes each of the previous estimates by source. Further, the observed environmental correlations are consistent with multiple domains of personality underlying the development of loneliness net of shared genetic factors. Across phenotypic, genetic, and environmental associations

[3] We considered removing items indexing Social Closeness as they are arguably overlapping with loneliness (e.g., "I often prefer not to have people around me" and "I usually like to spend my leisure time with friends rather than alone"), but ultimately did not as there were only 4 items in total and they index preferences for relationship closeness, rather than the feeling of being alone.

[4] Including opposite-sex DZ twin pairs in biometric models requires assumptions about the covariance between twins within pairs that cannot be verified; therefore we removed the opposite-sex DZ twin pairs to test if including them changed the estimates from the models.

Table 2
Univariate parameter estimates and fit statistics for loneliness, the big five, and MPQ traits.

Variable	MZ Pairs	DZ Pairs	MZ ICC	DZ ICC	a^2 [95 % CI]	d^2 [95 % CI]	c^2 [95 % CI]	e^2 [95 % CI]	AIC
Loneliness	173	241	0.26	0.16	0.21 [0.00–0.38]	–	0.06 [0.00–0.29]	0.73 [0.60–0.89]	2785.8
					0.28 [0.15–0.41]	0.00 [0.00–0.39]	–	0.72 [0.60–0.85]	2785.9
					0.28 [0.15–0.41]	–	–	**0.72 [0.60–0.85]**	**2783.9**
Neuroticism	170	243	0.44	0.06	0.37 [0.23–0.49]	–	0.00 [0.00–0.12]	0.63 [0.53–0.75]	2763.3
					0.00 [0.00–0.42]	**0.40 [0.00–0.53]**	–	**0.59 [0.49–0.71]**	**2760.1**
					0.37 [0.25–0.49]	–	–	0.63 [0.53–0.75]	2761.3
Agreeableness	171	243	0.35	0.16	0.34 [0.02–0.47]	–	0.00 [0.00–0.24]	0.66 [0.55–0.79]	2774.3
					0.28 [0.00–0.47]	0.06 [0.00–0.47]	–	0.65 [0.54–0.79]	2774.3
					0.34 [0.21–0.47]	–	–	**0.66 [0.55–0.79]**	**2772.3**
Extraversion	171	243	0.36	0.17	0.36 [0.05–0.50]	–	0.00 [0.00–0.23]	0.64 [0.53–0.77]	2771.8
					0.31 [0.00–0.50]	0.07 [0.00–0.50]	–	0.63 [0.51–0.76]	2771.7
					0.36 [0.24–0.50]	–	–	**0.64 [0.53–0.77]**	**2769.8**
Openness	169	240	0.36	0.17	0.36 [0.10–0.49]	–	0.00 [0.00–0.25]	0.64 [0.53–0.76]	2751.0
					0.32 [0.00–0.49]	0.04 [0.00–0.49]	–	0.63 [0.52–0.76]	2750.9
					0.36 [0.24–0.49]	–	–	**0.64 [0.53–0.76]**	**2748.9**
Conscientiousness	171	243	0.30	0.22	0.21 [0.00–0.48]	–	0.12 [0.00–0.35]	0.67 [0.54–0.83]	2772.6
					0.36 [0.23–0.49]	0.00 [0.00–0.37]	–	0.64 [0.53–0.77]	2773.3
					0.36 [0.23–0.49]	–	–	**0.64 [0.53–0.77]**	**2771.3**
Well-Being	172	244	0.29	0.11	0.27 [0.02–0.39]	–	0.00 [0.00–0.25]	0.73 [0.62–0.87]	2789.1
					0.19 [0.00–0.39]	0.08 [0.00–0.41]	–	0.72 [0.60–0.86]	2789.0
					0.27 [0.14–0.39]	–	–	**0.73 [0.62–0.87]**	**2787.1**
Social Potency	173	243	0.41	0.18	0.42 [0.24–0.55]	–	0.00 [0.00–0.19]	0.58 [0.48–0.70]	2767.5
					0.27 [0.00–0.55]	0.17 [0.00–0.56]	–	0.56 [0.46–0.70]	2767.1
					0.42 [0.33–0.55]	–	–	**0.58 [0.48–0.70]**	**2765.5**
Achievement	172	243	0.34	0.11	0.32 [0.08–0.45]	–	0.00 [0.00–0.17]	0.68 [0.57–0.81]	2780.1
					0.09 [0.00–0.43]	0.26 [0.00–0.49]	–	0.65 [0.53–0.79]	2779.2
					0.32 [0.19–0.45]	–	–	**0.68 [0.57–0.81]**	**2778.1**
Social Closeness	173	243	0.40	0.18	0.39 [0.09–0.52]	–	0.00 [0.00–0.22]	0.61 [0.51–0.73]	2768.9
					0.32 [0.00–0.51]	0.07 [0.00–0.51]	–	0.60 [0.49–0.73]	2768.9
					0.39 [0.36–0.52]	–	–	**0.61 [0.51–0.73]**	**2766.9**
Stress Reactivity	172	243	0.33	0.12	0.30 [0.00–0.42]	–	0.00 [0.00–0.24]	0.70 [0.59–0.83]	2781.1
					0.20 [0.00–0.42]	0.11 [0.00–0.43]	–	0.69 [0.57–0.83]	2781.0
					0.30 [0.18–0.42]	–	–	**0.70 [0.59–0.83]**	**2779.1**
Aggression	172	244	0.39	0.13	0.38 [0.21–0.51]	–	0.00 [0.00–0.15]	0.62 [0.52–0.75]	2775.5
					0.10 [0.00–0.49]	0.31 [0.00–0.55]	–	0.59 [0.48–0.73]	2774.2
					0.38 [0.25–0.51]	–	–	**0.62 [0.52–0.75]**	**2773.5**
Alienation	172	243	0.46	0.18	0.46 [0.26–0.59]	–	0.00 [0.00–0.14]	0.54 [0.45–0.66]	2755.9
					0.20 [0.00–0.57]	0.29 [0.00–0.61]	–	0.51 [0.42–0.64]	2754.5
					0.46 [0.33–0.59]	–	–	**0.54 [0.45–0.66]**	**2753.8**
Control	173	243	0.29	0.15	0.18 [0.00–0.39]	–	0.08 [0.00–0.30]	0.74 [0.62–0.88]	2786.7
					0.27 [0.04–0.39]	0.00 [0.00–0.37]	–	0.72 [0.61–0.85]	2786.9
					0.27 [0.15–0.39]	–	–	**0.72 [0.61–0.85]**	**2784.9**
Traditionalism	170	242	0.42	0.28	**0.18 [0.00–0.49]**	–	**0.21 [0.00–0.43]**	**0.61 [0.50–0.73]**	**2741.2**
					0.42 [0.24–0.53]	0.00 [0.00–0.27]	–	0.57 [0.49–0.68]	2743.6
					0.42 [0.31–0.53]	–	–	0.57 [0.49–0.68]	2741.6
Harm Avoidance	172	244	0.32	0.19	0.23 [0.00–0.45]	–	0.08 [0.00–0.32]	0.69 [0.57–0.83]	2779.7
					0.32 [0.00–0.45]	0.00 [0.00–0.40]	–	0.67 [0.57–0.80]	2780.0
					0.32 [0.21–0.45]	–	–	**0.67 [0.57–0.80]**	**2778.0**
Agency	171	243	0.41	0.12	0.37 [0.17–0.50]	–	0.00 [0.00–0.16]	0.63 [0.52–0.75]	2768.4
					0.08 [0.00–0.47]	0.32 [0.00–0.53]	–	0.60 [0.49–0.73]	2767.1
					0.37 [0.25–0.50]	–	–	**0.63 [0.52–0.75]**	**2766.4**

Note. MZ Pairs = Number of monozygotic twin pairs; DZ Pairs = Number of Dizygotic twin pairs; MZ ICC = Monozygotic intraclass correlation, or the correlation on a given trait across MZ twin pairs; DZ ICC = Dizygotic Intraclass correlation; AIC = Akaike Information Criteria; a^2 = additive genetic; d^2 = dominant genetic; c^2 = common environment; e^2 = unique environment. Maximum likelihood 95 % confidence intervals are displayed in brackets. Full ACE models are in the first row for each variable, followed by ADE and AE models. The bolded row is considered the best-fitting model, indicated by the lowest AIC.

with loneliness, magnitudes were largest for traits indexing high Negative and low Positive Emotionality.

Traits indexing Negative Emotionality had the strongest links with loneliness in the present study, replicating previous work (Schermer & Martin, 2019; Abdellaoui et al., 2019a). Notably, FFM Neuroticism and MPQ Stress Reactivity displayed strong phenotypic and genetic correlations, as well as moderate environmental correlations. Although loneliness is presumed to be largely shaped by environmental factors like social isolation, this suggests that being easily upset, irritable and nervous may be shaped in large degree by the same genes that influence loneliness. A plausible explanation for the observed effects is that Neuroticism can lead individuals to pick environments or evoke reactions from environments that lead to loneliness. MPQ Aggression and Alienation were also linked with loneliness. Alienation was more strongly associated phenotypically and genetically, but, unlike Aggression, did not display a significant environmental correlation. These results may indicate that aspects of Negative Emotionality that lead to interpersonal aggression or volatility may underly the development of loneliness (i.e., r_e), while interpersonal detachment or withdrawal may be shaped in larger degree by the same genes as loneliness.

Traits indexing low Positive Emotionality had similarly strong links with loneliness, replicating previous work (Schermer & Martin, 2019). Extraversion is conceptually linked to Positive Emotionality (Church, 1994). One model of extraversion separates it into "aspects" of Enthusiasm and Assertiveness (DeYoung et al., 2007), which are conceptually similar to communion and agency. Each of the MPQ traits subsumed under Positive Emotionality were associated with loneliness phenotypically and genetically. However, associations between loneliness and low Well-Being and low Social Closeness (i.e., facets of Enthusiasm) were stronger than associations between loneliness and low Social

Table 3
Personality trait correlations with loneliness.

Variable	Phenotypic	Semi-Partial**	Genetic	Unique Environment
MIDI				
Neuroticism	0.40*	0.33*	**0.55 [0.30 to 0.78]**	**0.31 [0.20 to 0.42]**
Agreeableness	−0.25*	−0.08	**−0.31 [-0.52 to −0.003]**	**−0.23 [-0.35 to −0.11]**
Extraversion	−0.34*	−0.15*	**−0.56 [-0.81 to −0.31]**	**−0.26 [-0.38 to −0.14]**
Openness	−0.23*	0.05	**−0.36 [-0.62 to −0.07]**	**−0.19 [-0.31 to −0.07]**
Conscientiousness	−0.27*	−0.11*	**−0.33 [-0.58 to −0.04]**	**−0.27 [-0.38 to −0.14]**
Agency	−0.22*	−0.05	**−0.32 [-0.58 to −0.04]**	**−0.16 [-0.28 to −0.04]**
MPQ				
Well-Being	−0.39*	−0.20*	**−0.63 [-0.88 to −0.35]**	**−0.32 [-0.42 to −0.20]**
Social Potency	−0.22*	−0.06	**−0.31 [-0.56 to −0.05]**	**−0.16 [-0.28 to −0.03]**
Achievement	−0.19*	0.01	**−0.32 [-0.62 to −0.01]**	**−0.13 [-0.26 to −0.01]**
Social Closeness	−0.28*	−0.12*	**−0.63 [-0.87 to −0.38]**	−0.11 [-0.23 to 0.01]
Stress Reactivity	0.42*	0.21*	**0.78 [0.53 to 1.00]**	**0.25 [0.14 to 0.36]**
Aggression	0.21*	−0.00	**0.30 [0.02 to 0.53]**	**0.19 [0.07 to 0.31]**
Alienation	0.30*	0.11*	**0.68 [0.54 to 0.94]**	0.11 [-0.01 to 0.24]
Control	−0.06	−0.01	−0.01 [-0.97 to 0.35]	−0.12 [-0.23 to 0.001]
Traditionalism	0.01	−0.01	0.06 [-0.16 to 0.28]	−0.01 [-0.14 to 0.11]
Harm Avoidance	−0.03	−0.03	0.12 [-0.17 to 0.46]	−0.09 [-0.21 to 0.03]

Note. * $p < .01$. **Covariation removed for other traits in the same scale (e.g. Residual correlation with Neuroticism removes covariation with other 4 of Big Five traits and Agency, while residual correlation with Well-Being removes covariation with other 9 MPQ traits). Correlations are reported after transformation procedures and after regressions that control for age and sex. Maximum likelihood 95 % confidence intervals in brackets; those which do not contain zero are deemed to be significant and in bold. In all bivariate cases, the reduced AE model had a lower AIC value than the ADE or ACE models, so only results from AE models are reported for genetic and environmental correlations. Well-Being, Social Potency, Achievement, and Social Closeness are subsumed by Positive Emotionality. Stress Reactivity, Aggression, and Alienation are subsumed by Negative Emotionality. Control, Traditionalism, and Harm Avoidance are subsumed by Constraint.

Potency and low Achievement (i.e., facets of Assertiveness); these associations remained significant in semi-partial correlations, perhaps indicating that Enthusiasm is more protective against loneliness than Assertiveness. Still, Social Potency and Achievement displayed negative environmental correlations with loneliness, though considerably smaller than that of Well-Being. Many domains of low Positive Emotionality may be relevant to the etiology and pathogenesis of loneliness, but the present study suggests that Well-Being demands particular consideration moving forward.

Genetic and environmental correlations with loneliness were significant for both low FFM Agreeableness and high MPQ Aggression, replicating previous work (Schermer & Martin, 2019; Abdellaoui et al., 2019b). MPQ Aggression is subsumed under Negative Emotionality in the MPQ (in much the same way the FFM Neuroticism domain includes hostility) but is also a strong marker for the negative pole of FFM Agreeableness (i.e., Antagonism; Church, 1994). However, unlike Negative Emotionality, low Positive Emotionality, and low Conscientiousness, neither (low) FFM Agreeableness nor MPQ Aggression remained significantly associated with loneliness after removing covariation with other personality traits, replicating prior evidence (Schermer & Martin, 2019; Abdellaoui et al., 2019a). This may indicate that Agreeableness is only linked to loneliness due to its covariation with traits like (low) Neuroticism and (high) Extraversion.

Conscientiousness, Achievement (positive emotionality facet) and Agency were all associated with loneliness phenotypically and genetically; however, the MPQ Constraint lower-order scales of Harm Avoidance, Control and Traditionalism were not associated with loneliness. This result may suggest that Conscientiousness can be protective against loneliness insofar as it leads to experiences that lead to feeling accomplished (e.g., Achievement, Agency, and Industriousness), but self-control and orderliness in and of themselves are less relevant in developing fulfilling interpersonal relationships that stave off loneliness. Moderate genetic and unique environmental correlations between low Openness and loneliness were observed, which is inconsistent with prior evidence (Schermer & Martin, 2019; Abdellaoui et al., 2019b). However, low Openness was not significantly associated with loneliness after removing covariation with other personality traits.

4.1. Limitations

This study has some noteworthy limitations. First, self-report scales were used for all variables. Therefore, the extent to which shared method variance contributed to the observed associations is unknown. Evaluative consistency bias, or the tendency for people to be consistent in rating themselves as having desirable qualities or not, may account for the shared method variance (Anusic et al., 2009). In addition, the use of relatively abbreviated scales (i.e., each construct was measured by three to seven items) may also contribute to shared method variance and, in some cases, limited internal consistency. Harrison et al. (1996) argue that scales with fewer items are more susceptible to shared method variance, as respondents are more easily able to mentally access their answers to previous scales. The results regarding Openness in particular should be evaluated through this lens, as larger than expected associations with loneliness were observed, perhaps due to strong mediating correlations with Extraversion and Conscientiousness. Future studies would benefit from incorporating information from multiple informants and longer scales.

Second, some of the intercorrelations between the Big Five domains have been shown to be consistent rather than artifactual (van der Linden et al., 2010), creating difficulty for inference on the uniqueness of trait contributions. The intercorrelations are thought to be indicative of two higher-order personality dimensions, known as Alpha and Beta (Digman, 1997), or Stability and Plasticity (DeYoung et al., 2002). Our study and others examined multivariate associations whereby the other four traits are controlled for in a semi-partial correlation between the trait of interest and loneliness. However, future work may benefit from treating these intercorrelations as meaningful indicators of superordinate constructs, rather than artifacts to be regressed out. In addition, as the MPQ does not directly assess narrower dimensions of the Big Five, future studies can incorporate formal Big Five aspects or facets. Alternatively, future researchers may consider fitting multivariate biometric models, such as the independent pathway model or common pathway model, to explore relations between the latent genetic components of each of the traits simultaneously (Neale & Maes, 2004; Kendler et al., 1987). These types of models can inform the degree to which the genetic and environmental influences on loneliness overlap with personality more broadly (e.g., with the whole Big Five) rather than with individual traits.

In addition, the consideration of possible covariates, such as

relationship status or stressful life events, for instance, may deepen the understanding of the relations between personality and loneliness in future studies with larger samples. More broadly, all data were cross-sectional, so inference on temporal sequencing is not warranted. An environmental correlation provides evidence of the co-occurrence of two phenotypes due to factors in the environment that make identical twins differ from each other (holding constant genetic similarity). Without longitudinal or experimental data, it is difficult to infer the direction of causality. Therefore, we only argue that this pattern of results is consistent with – rather than indicative of – personality traits underlying the development of loneliness, but loneliness could theoretically underlie the development of personality changes as well. Longitudinal evidence to date suggests bidirectional influences, with the effect of Neuroticism on loneliness being stronger than that of loneliness on Neuroticism (Abdellaoui et al., 2019a; Mund & Neyer, 2016). Finally, a third unmeasured environmental variable could underlie changes in both.

The inclusion of opposite-sex twin pairs may violate the equal environments assumption of the classical twin design. In these models, environmental factors are assumed to contribute to phenotypic similarity between MZ and DZ twin pairs equally. There were no large systematic differences in the ICCs across same-sex and opposite-sex DZ twin pairs (Supplemental Table S4) and the effects of sex were regressed out of study variables before analyses, but, even so, this may be too strong of an assumption given that all MZ twins are necessarily the same sex and some DZ twins are not. In the end, we opted to include all opposite-sex DZ twins for increased statistical power, an analytic decision supported by similar ICCs across same-sex and opposite-sex DZ pairs, and to conduct a sensitivity analysis wherein opposite-sex DZ twins were removed (Supplemental Tables S7 and S8). Results were largely consistent across analyses.

4.2. Conclusion

The present findings corroborate the importance of personality in understanding individual differences in the propensity to feel lonely. A wide range of traits, at varying levels of breadth, appear to be strong correlates of loneliness. The most important domains appear to be high Negative Emotionality, particularly being reactive to stress and feeling alone in the world, low Positive Emotionality, and low Conscientiousness. Further, these correlations are explained in varying degrees due to shared genetic and environmental factors, consistent with an etiology involving several domains of personality underlying the development of loneliness. Further research on the mechanisms underlying the co-development of personality and loneliness may inform future prevention and intervention efforts.

Author Note

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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.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jrp.2022.104314.

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