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Article

Genetic and Environmental Causes of Individual Differences in Borderline Personality Disorder Features and Loneliness are Partially Shared

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Abstract

Loneliness is related to mental and somatic health outcomes, including borderline personality disorder. Here, we analyze the sources of variation that are responsible for the relationship between borderline personality features (including four dimensions, affective instability, identity disturbance, negative relationships, self-harm and a total score) and loneliness. Using genetically informative data from two large nonclinical samples of adult twin pairs from Australia and the Netherlands ($N = 11{,}329$), we estimate the phenotypic, genetic and environmental correlations between self-reported borderline personality features and loneliness. Individual differences in borderline personality and loneliness were best explained by additive genetic factors with heritability estimates $h^2 = 41\%$ for the borderline personality total score and $h^2 = 36\%$ for loneliness, with the remaining variation explained by environmental influences that were not shared by twins from the same pair. Genetic and environmental factors influencing borderline personality (total score and four subscales separately) were also partial causes of loneliness. The correlation between loneliness and the borderline personality total score was $r_{\mathrm{ph}} = .51$. The genetic correlation was estimated at $r_{\mathrm{g}} = .64$ and the environmental correlation at $r_{\mathrm{e}} = .40$. Our study suggests common etiological factors in loneliness and borderline personality features.

Keywords: Borderline personality disorder; loneliness; twins; multivariate genetic models; genetic correlation

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Loneliness is the subjective experience of social isolation. In a comprehensive review of the evolutionary and heritability findings of loneliness, Cacioppo et al. (2014) argued that loneliness may have an adaptive function because loneliness is an 'aversive state that, like hunger, thirst, and pain, promotes behavior change to increase the likelihood of the survival of one's genes' (p. 3). Qualter et al. (2015) describe this need to reconnect with others when feeling lonely as the reaffiliation motive (reaffiliation model). However, the manner in which individuals cope with loneliness appears to vary. Although loneliness is a commonly experienced emotion, for many (with estimates of 15–30%), loneliness is a chronic condition that has a negative impact on mental and physical wellbeing (Hawkley & Cacioppo, 2010).

Loneliness appears to be a stable construct (Bartels et al., 2008; Boomsma et al., 2007; Junttila & Vauras, 2009) that has been found to be present in individuals at every stage of life and has been shown to be associated with a range of psychological constructs implicated in poor mental health or maladjustment. In childhood and early adulthood, loneliness is associated, for example, with insecure attachment to parents (Akdoğan, 2017; Mund & Neyer, 2016; Wiseman et al., 2006). Vanhalst et al. (2015) reported that adolescents who were chronically lonely viewed inclusion into groups as due to the situation, while exclusion from others was seen as caused by internal and stable characteristics. In adults, loneliness increases rates of mortality (Holt-Lunstad et al., 2015) and correlates positively with shyness (Cheek & Busch, 1981; Jackson et al., 2000), depressive characteristics (Besser et al., 2003), social anxiety (Jackson, 2007) and neuroticism (Saklofske & Yackulic, 1989; Saklofske et al., 1986; Stokes, 1985). Loneliness has also been found to correlate negatively with extraversion, self-esteem (de Jong-Gierveld, 1987), self-confidence (Cheng & Furnham, 2002), acceptance of others (Levin & Stokes, 1986) and mattering (Flett et al., 2016). Lonely people tend to make fun of themselves (Schermer et al., 2017) and engage in self-protective and social avoidant behavior (Knowles et al., 2015; Lucas et al., 2010); and lonely people tend to have higher anxiety because of their perceptions about their social skills (Solano & Koester, 1989).

Within personality disorders, borderline personality disorder (BPD) is a commonly diagnosed disorder that is positively related

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to anxiety, depression, hostility and impulsiveness, and negatively related to self-discipline and deliberation (American Psychiatric Association [APA], 2013; Bach & Sellbom, 2016; Lieb et al., 2004; Trull, 2001). As explained by Bach and Sellbom (2016), BPD as defined by the *Diagnostic and Statistical Manual of Mental Disorders (*5th ed.; APA, 2013) includes 'fear of abandonment, unstable relations, identity disturbance, impulsivity, self-destructiveness, affective lability, chronic emptiness, uncontrolled anger, and paranoia or dissociation' (p. 492, Table 2). This sensation of chronic emptiness and fear of abandonment may specifically contribute to loneliness for those with BPD (Lieb et al., 2004). Although loneliness and an intolerance of aloneness (Matthies et al., 2018) are prevalent in those with BPD, in a maladaptive manner, it may actually lead to the avoidance of others (vs. affiliation with others). For example, Hauschild et al. (2018) found that the loneliness drive to affiliate with others is actually reversed in people with BPD. For example, mimicking behavior tends to increasing social interactions and affiliation but, as found by Hauschild et al., those who reported feeling lonely were less likely to mimic others, suggesting that the lonely people may have greater difficulty interacting with other people. Hauschild et al. also indicated that people with BPD tend to expect future relationships to be negative and therefore may avoid forming bonds with others. This process has been noted previously and labeled as rejection sensitivity (e.g., see Gao et al., 2017) and may capture the general interpersonal ambivalence or anxiety often seen in those with BPD features (Lieb et al., 2004; Mącik, 2018).

While the use of categorical clinical diagnoses presents some advantages in the research and clinical contexts, the use of dimensional models has been recommended to gain a full understanding of personality disorders, their correlates and etiology (APA, 2013). Borderline personality features are present at different degrees in the general population, and as such, can be conceptualized and measured within a continuous or dimensional framework. These features cover the borderline spectrum and include self-harm behaviors, including suicide attempts, unstable affect or volatile emotions, identity problems or feelings of emptiness or lack of purpose, and negative relationships with others (e.g., intense sense of betrayal from others; Morey, 1991). Borderline personality features are positively correlated with neuroticism, antagonism, irresponsibility and introversion (Distel, Trull et al., 2009). Studies investigating the relationship between borderline personality features and loneliness find a positive correlation between the two dimensions, that is, higher levels of borderline personality features are associated with feeling lonelier. For example, Liebke et al. (2017) investigated loneliness in women with BPD compared to control women and found that women with BPD were lonelier; and specifically, loneliness for those women with BPD was associated with less diverse social networks and greater difficulty with interpersonal communication.

Loneliness is heritable (see review by Cacioppo et al., 2014), with genetic factors explaining ~35–48% of the variance in loneliness in adults (Boomsma et al., 2005; Distel et al., 2010; Schermer & Martin, 2019). The single-nucleotide polymorphism (SNP) heritability (the phenotypic variance accounted for by genotyped SNPs) of a categorical loneliness measure in the UK Biobank was 8.1% and of continuous loneliness measures, 4.2% (Abdellaoui et al., 2019). As outlined by Trull (2001), mood disturbance patterns and other borderline personality characteristics have familial components. Genetic factors explain between 40% and 45% of borderline personality features, according to twin studies from the Netherlands, Belgium and Australia (Distel et al., 2008; Distel, Rebollo-Mesa et al., 2009) and has been estimated to be 46% in a Norwegian twin study (Torgersen et al. 2012). Typically, it has been found that the remaining variance is due to unique environmental effects, while the common environment shared by family members or cultural transmission from parents to offspring does not significantly account for variation in borderline personality features. These results, in conjunction with the reaffiliation model (Qualter et al., 2015), suggest that uncovering the genetic and environmental relationships between loneliness and BPD would add to our understanding of how the two constructs are related beyond the phenotypic correlations typically examined.

In summary, borderline personality and loneliness have been found to be connected at a phenotypic level (Liebke et al., 2017), but the etiology of the relationship between the two constructs is unknown. Both borderline personality features (Distel et al., 2008; Distel, Rebollo-Mesa et al., 2009) and loneliness (Cacioppo et al., 2014) are partially heritable, as reviewed above. The present study examines the genetic and environmental (both unique and shared) contributions to the correlation between borderline personality features and loneliness.

Method

Participants

Twins took part in studies on health and wellbeing at the QIMR Berghofer Medical Research Institute in Australia (QIMRB; see Lynskey et al., 2012) and the Netherlands Twin Register (NTR; Boomsma et al., 2002; Ligthart et al., 2019). The Australian sample included 4820 twins from 3047 families distributed in 1773 complete pairs (265 monozygotic male pairs (MZM), 546 monozygotic female pairs (MZF), 176 dizygotic male pairs (DZM), 412 dizygotic female pairs (DZF), and356 opposite sex pairs (OS) and 1274 single twins with a mean age of 28.93 years (*SD* = 5.8, range = 15–40). The Dutch sample included 6509 twins from 4142 families distributed in 2367 complete pairs (361 MZM, 159 DZM, 1044 MZF, 431 DZF, and372 OS) and 1775 single twins, with a mean age of 33.71 years (*SD* = 12.44, range = 14 to 86). All twins, from complete and incomplete pairs, were included in the study. The data for this study are available by contacting the directors of the two twin registries who are listed as the last two co-authors on the manuscript.

Measures and Procedure

As part of studies on health and lifestyle, individuals from both countries completed the Borderline Features scale from the Personality Assessment Inventory (PAI-BOR; Morey, 1991; see also Distel et al., 2008) and the three questions assessing loneliness, as suggested by Hughes et al. (2004), from the revised UCLA Loneliness Scale (Russell et al., 1980). The questionnaires were completed online or via mail. The protocols were approved by the QIMR Ethics Research committee and by the Central Ethics Committee on Research Involving Human Subjects of the VU University Medical Centre, Amsterdam, an Institutional Review Board certified by the US Office of Human Research Protections (IRB number IRB00002991 under Federal-wide Assurance-FWA00017598; IRB/institute codes, NTR 03-181). In the Australian sample, the information reported at the youngest age was selected when several reports were available. The data collection in the Netherlands was part of NTR Survey 2004 (seventh survey within a longitudinal survey study in adolescent and adult participants). All participants provided informed consent and the data were screened for missing patterns and outliers (defined

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as observations outside a distance 1.5 times the interquartile range) by cohort and those cases were excluded in the analyses.

The PAI-BOR consists of 24 items that require responses on a four-point scale from 0 = *False, not true at all* to 3 = *Very true*. There are four six-item subscales comprising the PAI-BOR including: affect instability (high negative mood baseline, deficits in emotional regulations, high scores indicate highly emotional individuals who are quick to anger; Australian alpha = .76 and Dutch alpha = .71); identity problems (unstable sense of self that can manifest as chronic feelings of emptiness or boredom; high scores indicate the tendency of individuals to feel that they do not have a purpose in life; Australian alpha = .66 and Dutch alpha = .56); self-harm (high scores indicate individuals who tend to engage in risky behavior and possibly self-mutilation and suicide attempts; Australian alpha = .68 and Dutch alpha = .65); and negative relationships (fail to have stable and fulfilling relationships with other people; Australian alpha = .59 and Dutch alpha = .50). To avoid inflating the correlations with loneliness, the item 'I rarely feel very lonely' was removed from both the negative relationships scale total as well as the total borderline score. The internal consistency (coefficient alpha) value for the PAI-BOR scale without the loneliness item was .85 in the Australian sample and .78 in the Dutch sample (vs. .85 and .79, respectively, including the item) and alpha without the loneliness item did not change for the negative relationships scale in either sample.

The three items from the revised UCLA Loneliness Scale (Russell et al., 1980) by Hughes et al. (2004) ask how often an individual feels that they lack companionship, how often the individual feels that they were left out and how often the individual feels that they are isolated from others. Responses to these items were on a 1 = *Hardly ever* to 3 = *Often* scale. The internal consistency (coefficient alpha) for the loneliness scale was .82 for the Australian sample and .74 for the Dutch sample.

Statistical Analyses

The classic twin design was employed to decompose the variance of borderline features and loneliness into additive genetic (A), non-additive or dominant genetic (D), shared environmental (C) and unique environmental (E) variance components (note the E component includes measurement error). This is achieved with a model that compares monozygotic (MZ) and dizygotic (DZ) twins within twin pair correlations. MZ twins share all their genetic variants, while DZ twins share, on average, half of their additive genetic variants. Based on biometrical genetic theory, this means that all additive and dominant genetic variances are shared by MZ twins. DZ twins share half of the additive genetic and a quarter of the dominant genetic variance. Both MZ and DZ twins experience environments that are shared, and therefore in common by both twins in a pair, which may contribute to their resemblance. In addition, each twin within a pair has experiences that are unique and also contribute to trait variation. From these relationships, a structural equation model is specified. However, with only MZ and DZ correlations, all four sources of variation cannot be identified and either C or D is excluded from the model after inspection of the twin correlations. If the DZ twin correlation is less than half the MZ twin correlation, then D is estimated along with A and E, otherwise C is estimated. From a full model with three parameters, such as an ACE model, nested models are used to test the significance of variance components; for example, evaluating the significance of C by running an AE submodel. With the data in this study, parameters were estimated by raw data maximum likelihood, and a likelihood ratio test was applied to test if the nested (or reduced) model fit the data less well than the full model (Posthuma et al., 2003). Age and sex were included as fixed effects in the variance component analyses. All analyses were conducted in R and OpenMx (Boker et al., 2011).

First, we assessed within each country whether means, variances and covariation could be equated across birth order, sex and zygosity. Next, MZ and DZ twin correlations were estimated, and ACE or ADE univariate models for loneliness and each of the borderline measures were fit to the data within each cohort. We then tested, in a multiple group model, whether variance component parameters could be equated across the Australian and Netherlands samples and the data combined for subsequent bivariate analyses.

Bivariate models were fitted to the data to quantify the extent that genes and the environment contribute to the observed phenotypic correlations between loneliness and borderline features. Five bivariate Cholesky decomposition analyses were conducted between loneliness and each of the borderline subscales and the borderline total score. A Cholesky decomposition partitions the variation of the initial variable (the borderline score) into genetic and environmental sources and estimates the extent those sources also contribute to the second variable (loneliness). Any remaining variation in loneliness that is independent of the borderline is also decomposed into genetic and environmental sources. With this model, we tested whether the phenotypic covariation between borderline and loneliness was due to genes or to the environment. Based on the results, a genetic and an environmental correlation were estimated between the two traits.

Results

Table 1 reports the descriptive statistics for each scale for men and women separately for the Australian and Dutch samples. Means and variances tended to be higher in the Australian cohort, both in the total sample and stratified by sex. For this reason, the variables were standardized within cohort to a mean of 0 and a standard deviation of 1. Because the data on all scales showed a somewhat skewed distribution, a square root and a logarithmic transformation were performed for the borderline personality variables and loneliness, respectively.

Assumptions of the twin design were checked, including the homogeneity of the means and variances of first- and second-born twins and across zygosity groups, and it was found that the assumptions were met. The effect of sex and age on the mean of the variables was also evaluated within cohort. With the exception of identity problems in the Dutch cohort, age had significant negative correlations with the variable scores. With respect to sex differences, females had higher means for the scale's identity problems, negative relationships and self-harm within the Australian sample, and had higher means for all of the variables, except identity problems, in the Dutch sample.

Twin correlations could be equated for MZ pairs regardless of sex, and the same constraint was allowed for all DZ pairs. When testing, a sex limitation model and assuming the same sources of variances of the same magnitude for males and females, these constraints were allowed, thus discarding the need to stratify the variance components by sex. The first panel of Table 2 provides the twin correlations for MZ and DZ twins for the borderline personality scales and loneliness. For each scale, the MZ correlation was higher than the DZ correlation, suggesting genetic effects.

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Table 1. Descriptive statistics by country and sex

	Males		Females	
	Australian *N*; *M* (*SD*)	Dutch *N*; *M* (*SD*)	Australian *N*; *M* (*SD*)	Dutch *N*; *M* (*SD*)
Affect instability	1745; 4.48 (3.11)	1993; 4.32 (2.90)	3013; 4.66 (3.18)	4443; 4.86 (3.05)
Identity disturbance	1743; 4.72 (2.89)	1975; 3.76 (2.45)	2988; 4.97 (3.04)	4389; 4.39 (2.67)
Negative relationships[1]	1709; 3.19 (2.16)	1957; 3.19 (2.11)	2915; 3.38 (2.28)	4357; 3.39 (2.14)
Self-harm	1736; 3.66 (2.66)	1925; 2.58 (2.02)	3009; 3.14 (2.57)	4316; 2.56 (2.01)
Borderline total score[1]	1727; 16.06 (8.31)	1963; 13.95 (7.06)	2970; 16.17 (8.61)	4355; 15.20 (7.09)
Loneliness	1765; 4.47 (1.66)	1992; 4.04 (1.31)	3055; 4.54 (1.67)	4455; 4.26 (1.38)

Note: [1]The item asking if people rarely feel lonely.

Table 2. Monozygotic (MZ) and dizygotic (DZ) twin correlations with 95% confidence intervals (CIs) by cohort for each of the phenotypes (note the twin correlations within zygosity could be equated regardless of sex) and proportions of variance explained by additive genetic (A) and residual variation (E) with 95% CIs from the univariate best fitting models (note the Australian and Dutch parameters could be equated)

	Australian sample		Dutch sample		Parameter estimates	
	r_{MZ} [95% CIs]	r_{DZ} [95% CIs]	r_{MZ} [95% CIs]	r_{DZ} [95% CIs]	A [95% CIs]	E [95% CIs]
Affect instability	.34 [.28, .40]	.14 [.07, .20]	.37 [.32, .41]	.12 [.06, .18]	.34 [.30, .37]	.64 [.61, .68]
Identity disturbance	.39 [.33, .44]	.14 [.08, .21]	.34 [.29, .38]	.15 [.09, .21]	.33 [.29, .37]	.62 [.59, .65]
Negative relationships[1]	.32 [.26, .38]	.22 [.16, .29]	.35 [.30, .39]	.18 [.12, .24]	.34 [.30, .38]	.65 [.61, .68]
Self-harm	.35 [.29, .41]	.13 [.06, .19]	.31 [.26, .36]	.10 [.04, .16]	.31 [.27, .35]	.68 [.65, .72]
Borderline total score[1]	.46 [.40, .50]	.17 [.11, .23]	.42 [.38, .47]	.16 [.10, .22]	.41 [.37, .45]	.56 [.53, .59]
Loneliness	.37 [.31, .43]	.21 [.15, .26]	.37 [.32, .41]	.10 [.04, .17]	.36 [.32, .39]	.63 [.60, .67]

Note: [1]The item asking if people rarely feel lonely.

According to the observed twin correlations and comparing the magnitude of the within twin pair correlations for MZ versus DZ twins, ACE univariate models were fit for the negative relationships scale in both the Australian and Dutch samples. An ACE univariate model was also fit for the loneliness scale scores for the Australian sample. ADE univariate models were fit for the rest of the scales. The variance components of the full models could be equated across cohorts, meaning that the proportion of each of the sources of variance was equivalent and there was no need to stratify the analyses by cohort. Nested models were then tested against the full ACE or ADE models. The best fitting model in all cases was an AE model, which explains the variance observed by additive genetic (A) and unique environmental factors (which include the measurement error; E). The right-hand panel of Table 2 summarizes these results, showing that additive genetic effects account for between 31% (for the self-harm scale) and 41% (for the total Borderline scale score) of the variance and that most of the variance was accounted by unique environmental factors and measurement error.

The results of the bivariate analyses between loneliness and the borderline personality dimensions are reported in Table 3. All aspects of borderline personality were found to have significant positive phenotypic correlations (r_{ph}) with loneliness, with the lowest estimate for the subscale self-harm ($r_{ph} = .17$) and the highest estimates for the total score of the borderline personality questionnaire and identity disturbance showing $r_{ph} = .51$ and $r_{ph} = .54$, respectively. Consistent with the univariate analyses, the bivariate genetic models showed that the AE model had the best fit to the data. As detailed in Table 3, the results indicate substantial genetic influences on loneliness that were shared with borderline features (A_{12}) as well as genetic influences on loneliness that were independent of borderline features (A_{22}). Unique environment effects also influenced loneliness as well as borderline features, yet most of these influences on loneliness were independent of any influence on borderline features (E_{22}). The genetic correlations between loneliness and borderline features ranged from 0.30 for the self-harm scale to 0.74 for the identity disturbance scale. Common unique environmental influences between loneliness and borderline features were lower than the common genetic sources, with the highest unique environmental correlations for identity disturbance ($r_e = .41$) and the lowest for self-harm ($r_e = .1$). The proportion of the phenotypic correlation between the total score of the PAI-BOR and loneliness due to genetic factors was 51%. For the subscales, the proportion of the phenotypic correlation with loneliness due to genetic factors was 54%, 47%, 57% and 60% for affective instability, identity disturbance, negative relationships and

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Table 3. Model-fitting results for bivariate models (Cholesky decomposition) for the borderline traits and loneliness and proportions of variance and covariance explained by additive genetic (A) and residual variatio (E) with 95% confidence intervals (Australian and Dutch samples combined)

Borderline trait	A_{11}	A_{12}	A_{22}	E_{11}	E_{12}	E_{22}	r_{ph}	r_a	r_e
Affective instability	.37 [.34, .40]	.16 [.13, .19]	.21 [.18, .24]	.63 [.60, .66]	.07 [.05, .08]	.57 [.54, .59]	.45 [.43, .46]	.66 [.61, .71]	.32 [.29, .35]
Identity disturbance	.40 [.37, .43]	.20 [.17, .23]	.17 [.14, .19]	.60 [.57, .63]	.10 [.09, .12]	.53 [.50, .56]	.54 [.52, .55]	.74 [.69, .78]	.41 [.38, .44]
Negative relationships	.37 [.33, .40]	.13 [.10, .16]	.24 [.21, .27]	.63 [.60, .67]	.04 [.03, .06]	.59 [.56, .62]	.38 [.36, .40]	.59 [.53, .65]	.26 [.22, .29]
Self-harm	.32 [.28, .35]	.03 [.02, .05]	.33 [.30, .37]	.68 [.65, .72]	.01 [0, .01]	.63 [.59, .66]	.17 [.15, .19]	.30 [.23, .38]	.10 [.06, .14]
PAI-BOR total scale	.46 [.43, .49]	.17 [.15, .20]	.19 [.17, .22]	.54 [.51, .57]	.10 [.08, .12]	.53 [.51, .56]	.51 [.50, .53]	.64 [.69, .73]	.40 [.37, .43]

Note: ^{11} The proportion of variance explained in the borderline trait; ^{12} The proportion of covariance explained in the borderline trait and loneliness; ^{22} The proportion of variance explained in loneliness. r_{ph}, phenotypic correlation, r_a, genetic correlation, and r_e, environmental correlation.

self-harm, respectively. Thus, approximately half of the correlation value observed between loneliness and the borderline personality dimensions is due to genetic factors.

Discussion

This study examined the relationship between borderline personality features and loneliness at the phenotypic, genetic and environmental levels and confirmed that individual differences in the PAI-BOR subscales and total score and in loneliness were explained by a combination of additive genetic and environmental factors. The heritability estimates, which ranged from 31% for the borderline subscale self-harm to 41% for the borderline total score, are either the same or somewhat lower than estimates reported previously (Boomsma et al., 2005; Distel, Rebollo-Mesa et al., 2009; Schermer et al., 2015; 2017; please note that the samples partially overlap, but that the Australian sample in the present study is substantially larger than what has been used in previous research).

Consistent with previous findings of the relationship between BPD and loneliness (Liebke et al., 2017), the phenotypic correlation between loneliness and the total scale of BPD was .51. At the subscale level, loneliness was found to have positive and significant correlations, ranging from .17 for self-harm to .54 for identity disturbance. The factors underlying the phenotypic variance–covariance structure were partially genetic and partly due to unique environmental factors. Specifically, loneliness was found to have a genetic correlation with the total BPD scale of .64 and a unique environmental correlation of .40. For the BPD subscales, the genetic correlations with loneliness ranged from .30 with self-harm to .74 with identity disturbance.

Self-harm at the extreme level involves the risk of suicide and injury, but at more moderate levels includes impulsive spending and other risk-taking behaviors (Morey, 1991). Suicidal ideation is a common characteristic of individuals at the extreme level of self-harm. In a large sample of Danish students, Lasgaard et al. (2011) reported that suicidal ideation was associated with both peer-related and family-related loneliness but that deliberate self-harm was only associated with family-related loneliness. Possibly, the weaker correlation found in the present study may be due to not assessing the type of social loneliness experienced by the participants in relation to the self-harm scale. Specifically, as stated above, participants in this study were asked the degree to which they felt that they lacked companionship, felt left out and felt isolated from others. Possibly, a stronger relationship might have been found if the items specified certain groups, such as feeling left out of family activities versus social groups. Of interest, future research may assess the possible differences in the magnitude of the phenotypic, genetic and environmental correlations between borderline personality scales and types of social loneliness. For example, Liebke et al. (2017) found that individuals with BPD were less lonely when they had a greater social network. Asking participants to provide more detail about their social interactions and the possible causes of their loneliness would aid in the understanding of how borderline personality features are linked with types of loneliness.

The moderately strong correlation between loneliness and the BPD subscale of negative relationships at the phenotypic and genetic levels, with low to moderate unique environmental correlations, is not surprising in light of the finding that people with BPD tend to report failed past relationships and predict that future social interactions will be negative (Hauschild et al., 2018). Loneliness alone has been linked with a tendency to produce negative evaluations of relationships (Jones et al., 1983). In addition, Mellor et al. (2008) reported that lonely people had a greater difference between the need to belong and relationship satisfaction than less lonely people. These results do suggest that future research may be needed to examine if cognitively altering perceived negative relationships for those with borderline personality features will, in turn, result in reports of lower scores on loneliness measures.

Affect instability, characteristic of rapid and extreme moods, had a moderately strong correlation with loneliness at both the phenotypic and genetic levels and weaker correlations due to unique environmental factors. Recently, Anupama et al. (2018) concentrated on the affect regulation and difficulties with interpersonal relationships for patients with BPD and found that individuals with BPD had difficulty recognizing positive and neutral emotions depicted in photographs. Possibly having difficulty comprehending the emotions of others leads to more extreme reactions for people with BPD, which in turn may result in an increase in perceived isolation and loneliness. Providing training or guidance for those with borderline personality features on how to interpret facial expressions correctly may reduce feelings of loneliness by improving interpersonal interactions.

The BPD subscale of identity disturbance characterizes individuals who have problems with their sense of self-worth. Morey (1991) describes people who score high on the identity problems scale as 'feeling empty, bored, or unfulfilled' (p. 17). Strong phenotypic and genetic correlations were found between loneliness and identity disturbance with a moderately strong unique environmental correlation. This pattern of correlations may reflect the finding reported by loneliness researchers who describe lonely people as socially avoidant and self-protective (Knowles et al., 2015; Lucas et al., 2010). Similarly, Flett et al.'s (2016) concept of *mattering* also explains the strong correlations found as those who feel that they do not matter also report being lonely. Although the genetic basis of mattering appears to be unknown, it would be interesting for

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future research to examine the genetic and environmental links between mattering, loneliness and BPD. Because a low sense of self-worth is strongly linked with loneliness, then treatment programs aimed at improving a sense of self-worth and/or feelings of mattering to others would facilitate an individual's expressions of loneliness. In addition, although the genetic correlations were very robust, the unique environmental correlation between loneliness and identity disturbance was also significant suggesting that changes within the individual's environmental experiences may influence scores on both variables. Future studies may make use of longitudinal data, molecular genetic data and analysis techniques such Mendialian randomization to further explore for models of causality.

Limitations

Although this study adds to the understanding of BPD and loneliness, the study is cross-sectional and therefore cannot make claims as to whether BPD characteristics have a causal influence on loneliness or if loneliness increases the likelihood of an individual to score higher on BPD items. The results do attest that for some of the variance, there is a common basis for both loneliness and BPD features to co-occur, but as the significant unique environmental correlations demonstrate, not all of the associations are due to common genetic factors. How experiences increase feelings of loneliness or contribute to borderline personality features, such as identity disturbance requires further research.

In addition, a possible limitation of the present study is that the results for the borderline personality features scales reflect those within a normal range and cannot be generalized to a clinical population. A further limitation in the present study was the use of the three-item loneliness scale. Although the three items from the UCLA Loneliness Scale (Russell et al., 1980) used in the present study from Hughes et al. (2004) is a frequently used measure in the loneliness literature, findings such as the ones reported by Lasgaard et al. (2011) do suggest that different aspects of loneliness (peer-related versus family-related) may have differing effects on other psychological expressions. Future studies may want to further investigate the borderline personality correlates with multiple areas of loneliness to further understand how the social networks and loneliness relate to borderline personality dimensions.

Conclusions

In conclusion, the present study found positive correlations between BPD dimensions and loneliness. As significant heritability for both constructs was confirmed, bivariate genetic analyses were conducted and found that for all of the scales, approximately half of the covariance at the phenotypic level was due to common genetic factors, with the remainder of the phenotypic covariance due to experiences unique to each twin within the pair. Importantly, the present study provides information about the sources of the phenotypic correlations between borderline personality and loneliness demonstrating substantial and significant genetic and unique environmental correlations between the borderline personality features and loneliness, meaning that these traits partially share causal pathways. This is a promising finding for interventions aiming to decrease loneliness in people with high scores in borderline personality traits, since it implies that there is a substantial proportion of the correlation that is due to factors that can potentially be modified. Given the impact of loneliness in health outcomes and the relationship with mental health, the findings of the present study add important information for understanding the factors influencing these relationships.

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