Loneliness and Personality: Noise- and Bias-free True Correlations Between Loneliness and the Big Five Personality Domains

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Abstract

Loneliness is intertwined with many mental and physical health problems. While its origins remain unclear, loneliness has been linked to personality traits. Combining self- and informant ratings in multiple samples, we conducted the largest study to date to examine the true correlations (r_{true}s) between loneliness and the Big Five personality traits, free of single-method biases and transient and random errors. Across three samples (Estonian-speaking, N = 20,893; Russian-speaking, N = 762; English-speaking, N = 599), we found a strong relationship between loneliness and Neuroticism (r_{true} = .60 to .70). Loneliness also had robust but much weaker associations with Extraversion (r_{true} = -.20 to -.30), and only weak associations (r_{true} = 0.10 to -.20) with Agreeableness, Conscientiousness, and Openness. Collectively, the Big Five accounted for over 50% of loneliness variance. In a subsample, the associations were only slightly smaller longitudinally, over approximately 10 years. Leveraging familial relatedness among Estonian-speakers, we also found that these associations reflected both genetic and environmental factors to approximately the same degree for Neuroticism, but more variedly for other traits. Overall, feeling lonely is more closely related to Neuroticism than previously understood, the association endures over time, and is similarly accounted for by genetic and environmental factors.

Keywords: Loneliness, disconnection, personality, Neuroticism, true correlations, multi-rater

Introduction

Loneliness is receiving considerable attention from researchers, policy-makers and the public as it has become implicated in a growing number of adverse health outcomes, including cognitive decline, depression, anxiety, suicide, contracting infectious diseases, and all-cause hospitalisation and mortality (Deason et al., 2025; Holt-Lunstad et al., 2015; OSG, 2023). Loneliness is not synonymous with social isolation: for example, the UK's National Health Service defines loneliness as 'the feeling of being alone or isolated' while it defines social isolation as 'lack of social contact or support' (Veazie et al., 2019, Appendix F). Therefore while social isolation is considered objective (Gardiner et al., 2018), loneliness can be understood as a subjective feeling or emotion. There are also empirical reasons to distinguish between the two (Coyle & Dugan, 2012). For example, some (Ganesan et al., 2021; Gunnell et al., 2020; Reger et al., 2020) predicted that the surge in isolation due to lockdowns across the COVID-19 pandemic would result in a global increase in loneliness and suicides. In fact, suicides fell in 2020 (Pirkis et al., 2021) and did not rebound in 2021 (Dattani et al., 2023). Moreover, a meta-analysis of loneliness before and during the pandemic found that while loneliness itself did increase, the observed effects were heterogeneous and relatively small (*Standardized Mean Difference* = .27), in comparison to the change in circumstances (Ernst et al., 2022). So, loneliness levels may at least partly reflect more internal factors like genetic variation and relatively stable personality traits (Abdellaoui et al., 2019; Tapia-Munoz et al., 2023; Vanhalst et al., 2013). However, the strength and nature of the personality trait-loneliness association have remained unclear.

Existing evidence and its limitations

A meta-analysis of the relationship between loneliness and the Big Five personality traits found that Extraversion ($r = -.37$) and low Neuroticism ($r = .36$) were the strongest correlates of loneliness, while Agreeableness ($r = -.24$), Conscientiousness ($r = -.20$), and Openness ($r = -.11$) had weaker associations (Buecker et al., 2020); their broad findings also persisted in their multivariate analyses. Loneliness is usually a negative emotion, and as Neuroticism is defined as a general tendency to experience negative emotions, their relationship is unsurprising. In fact, it may even seem surprising that the association is not stronger; for example, one of the most widely used Neuroticism scales even includes an item directly referring to feeling lonely ('*I rarely feel lonely or blue*'; Costa & McCrae, 1992). Deason et al. (2025) found that Neuroticism and loneliness also share a highly similar pattern of links to mortality, and argued it was surprising loneliness is not used as an item in more short Neuroticism scales. Extraversion, in contrast, reflects general tendencies to feel positive emotions and engage in social interactions, so its negative relationship with loneliness is also unsurprising. To the extent that loneliness does reflect a lack of social connections, this can account

for its correlation with Agreeableness, given that dis-agreeableness does not foster social connections. As for the smaller correlations with the other Big Five, their interpretation is less obvious.

However, because psychometric measurement is inherently noisy, these numbers cannot be taken at face value. For example, typical test-retest ($r \approx .90$) and cross-rater correlations ($r \approx .50$) mean that about 10% of personality trait assessment's variance comprises random or occasion-specific error, while another 40% reflects stable variance not specific to the assessment source method (i.e., rater) such as socially desirable, extreme or acquiescent responding or unique item interpretations (Costa & McCrae, 1998; McCrae & Mõttus, 2019). So, only about 50% of trait scores' variance is reliable and consensually valid, and can therefore be interpreted as pertaining to the traits themselves, rather than the measurement process – challenges which the assessment of loneliness (or any other construct) is not exempt from. Random and occasion-specific errors lower correlations, but stable biases can both attenuate (e.g., unique item interpretations) and inflate (response styles) correlations, obscuring our view of variables' relationships. Unfortunately, scientists usually fail to heed these important issues.

Fortunately, these measurement artefacts can be addressed by using multiple assessment sources such as self-reports and ratings by close informants such as partners, close relatives or friends (Hoyt, 2000; Schimmack, 2010; Schmidt & Hunter, 1996). Specifically, correlations between those parts of personality traits' (e.g. Extraversion) and loneliness' variance on which two knowledgeable raters agree cannot be influenced by random or transient error nor single assessment source biases. Hence, these associations must represent the variables' valid, or 'true', correlations (r_{true}s; Henry et al., 2024; Mõttus et al., 2024). Combining the two assessment sources to obtain an estimate of the r_{true}s does not require equal or even particularly high cross-rater correlations as long as there is some cross-rater agreement, for which there is strong evidence for both personality traits (Connelly & Ones, 2010) and loneliness (Luhmann et al., 2016; Matthews et al., 2022). Supporting this, personality traits' associations with life satisfaction (Mõttus et al., 2024) and psychopathology (Soodla et al., 2024) were shown to be considerably stronger in the raters' shared variance than in single-source variance, and the traits familial transmission is also underestimated in single-method data (Mõttus et al., 2025; Riemann et al., 1997).

Although researchers have suggested supplementing self-reports with informant reports to examine the associations of personality traits with loneliness Buecker et al. (2020), there have been very few efforts to do so. In Matthews et al. (2022), for example, young people's loneliness was rated by both themselves and an interviewer, whereas the interviewer also rated their Big Five personality

traits. In this cross-assessment source correlation design, Neuroticism was the highest loneliness' correlate (r = .31), followed by Agreeableness (r = –.20) and Extraversion (r = –.12); for the other two traits $|r| < .10$. However, the authors did not model the correlations in raters' shared variance, which could have been considerably higher (Mõttus et al., 2024; Soodla et al., 2024). Moreover, interviewers may not have been the most knowledgeable sources of personality ratings, leading to underestimated associations. Teppers et al. (2013) reported the correlations between self-reported Big Five and peer- and parent-reported loneliness in young people, finding the correlations to be much stronger for the latter, especially for Extraversion (r = –.51). Notably, however, one of the few items used to assess Extraversion referred to being 'withdrawn', which is semantically close to being lonely and may have artifactually inflated the correlation. Likewise, these authors did not consider raters' shared variance.

Sources and stability of the associations

Personality traits and loneliness vary among individuals for genetic and environmental reasons (Distel et al., 2010; Vukasović & Bratko, 2015), and their correlations may also result from both sources (Abdellaoui et al., 2019; Schermer & Martin, 2019). In principle, therefore, their overlap may be because they share variance components stemming back to the family of origin or because unique life experiences shape them together – or a mix of both. For example, life satisfaction's overlap with personality traits is mostly, but not completely, due to overlapping genetic influences (Mõttus et al., 2025; Pelt et al., 2024; Weiss et al., 2008). Gaining a clearer understanding of this dynamic in relation to loneliness will help us understand the origin and development of loneliness across the lifespan.

For example, using a twin design, Schermer and Martin (2019) showed that Neuroticism had a strong genetic correlation with loneliness (r_{gen} = .81) and a smaller unique environmental correlation r_{env}= .48; for Extraversion, Agreeableness and Conscientiousness, the correlations were smaller but followed a similar pattern. Likewise, leveraging genomic similarity variations among familially unrelated individuals, Abdellaoui et al. (2019) showed a strong genetic correlation between Neuroticism and loneliness (r_{gen} = .71), with further evidence that their association may emerge through reciprocal causation. However, no multi-method study has assessed the genetic and environmental associations of loneliness with personality traits, which may be biased in single-method studies for the same reasons that the phenotypic associations they report are likely biased (Mõttus et al., 2025).

To the extent that loneliness' associations with personality traits are due to genetic reasons, they should endure over time, either because both are influenced by the same distal factors or because they have long-term bi-directional associations (Abdellaoui et al., 2019; Mund & Neyer, 2016; Tapia-Munoz et al., 2023), consistent with the corresponsive principle of development (Roberts & Nickel, 2017). Stable environmental factors can also contribute to the stability of personality traits-loneliness associations, while shorter-term influences such as specific life events could make longitudinal associations considerably smaller than contemporaneous ones. However, no multi-method study has addressed the long-term stability of loneliness-personality trait associations.

Current study

We carried out the largest yet, to our knowledge, multi-rater, multi-method investigation into loneliness' r_{true}s with personality traits. Specifically, we used self- and informant-ratings for loneliness and Big Five personality traits in the large Estonian- and Russian-speaking subsamples of the Estonian Biobank (EstBB) and in an additional English-speaking sample. Since a subsample of Estonian-speakers also had self-and informant-reported personality assessments from approximately ten years before the loneliness assessment, we could additionally test their longitudinal r_{true}s. Moreover, as another subsample of Estonian-speakers also contained pairs of first- and second-degree relatives, we were able to decompose the associations into genetic and unique environmental r_{true}s.

Materials & Methods

Openness and transparency

Our sampling strategies were governed by practical constraints rather than power calculations, but the samples provided high power to detect any non-trivial effect sizes. Supplementary materials, along with the data for English speakers, is available at https://osf.io/jmc8w. Data for the Estonian- and Russian-speaking samples cannot be made publicly available, but researchers can apply for access (https://genomics.ut.ee/en/content/estonianbiobank).

Participants

Estonian- and Russian-speaking participants were members of the EstBB, a population sample of over 200,000 adults, representing about 20% of Estonian residents (Milani et al., 2024). Between November 2021 and April 2022, 182,405 EstBB members were invited to participate in the second cohort of the EstBB Personality Study (Vaht et al., 2024) either in Estonian or Russian. Estonia has a substantial Russian-speaking minority, with partly distinct cultural and historical backgrounds (Vihalemm et al., 2019), so we treated Estonian- and Russian-speakers as separate samples. A total of $N = 77{,}400$ members completed the survey, receiving feedback on their Big Five personality traits, and could optionally provide an informant's email for third-person personality assessments. In both samples, we limited participants to those who were also rated by an informant and had no more than 10 missing personality item responses in either rating type, leaving us with $N = 20{,}893$ Estonian speakers (biological sex: 14,237 female, 6,656 male; age range 18 to 93, $M = 45.19$, $Mdn = 44$, $SD = 13.69$) and $N = 762$ Russian speakers (biological sex: 530 female, 232 male; age range 18 to 88, $M = 43.48$, $Mdn = 43$, $SD = 12.94$). Among all the informants, 57% were partners, 6% were parents, 14% were children, and 13% were friends. A portion ($N = 514$) of the Estonian-speaking participants had also taken part in the first cohort of the EstBB personality study between 2008 and 2018 (Vaht et al., 2024), including personality assessment with both self- and informant-reports (biological sex: 321 female, 193 male; age range 26 to 88, $M = 48.83$, $Mdn = 48$, $SD = 13.12$). Most had taken the survey by 2013, so the time interval between the two assessments was approximately 10 years.

Among the Estonian-speaking participants, we could identify 1,129 pairs of relatives by combining genomic similarity analysis and demographic information: parent-offspring pairs ($N_{pairs} = 522$), sibling-sibling pairs ($N_{pairs} = 388$), and second-degree relative pairs ($N_{pairs} = 476$). The identification procedure, participant exclusion criteria and demographic details of this subsample are given in Mõttus et al. (2025). This subsample allowed us to decompose associations into additive genetic and unique environmental contributions, justifiably assuming no shared (common-to-family-members) environmental influences, given the known genetic relatedness' among the relatives.

Additionally, between March and June 2020, 300 dyads completed personality assessments about themselves and their dyad partner in English. These participants included mostly United Kingdom residents, but some were from other European countries, India, or the United States. Participants received feedback on their personality traits and agreement with their informant's ratings, and some participants received monetary compensation (Mõttus et al., 2024). After exclusions for incomplete responding (10 or more missing responses), the final sample included N = 599 English speakers (sex: 402 women, 190 men, 7 preferred not to say; age range 12 to 82, M = 28.7, Mdn = 23, SD = 13.15). Relationships between informants and targets were not recorded for this sample.

Measures

EstBB personality study: second (main) cohort. Targets and their informants completed the 100 Nuances of Personality (100-NP; Henry & Mõttus, 2022), which is a pool of 198 items selected to assess personality traits comprehensively, reliably and with minimal overlap. This item pool covers trait content covered by common Big Five measures and traits beyond these, like envy, life satisfaction, humour, sexuality, spirituality, and loneliness. The items were iteratively selected from larger item pools like the International Personality Item Pool (Goldberg, 1999) and Synthetic Aperture Personality Assessment (Condon & Revelle, 2016) for maximally comprehensive coverage of the entire trait universe, and retained if they demonstrated acceptable empirical properties, including test-retest reliability, variance, and cross-rater agreement as an indicator of consensual validity (McCrae & Costa, 1987). A full description of the 100-NP's items and development can be found in Henry and Mõttus (2022), while the rationale for using this item pool over existing trait measures is articulated in Anni et al. (2024). The items were initially selected in English but translated to Estonian and Russian with multiple rounds of back-translations and expert discussions.

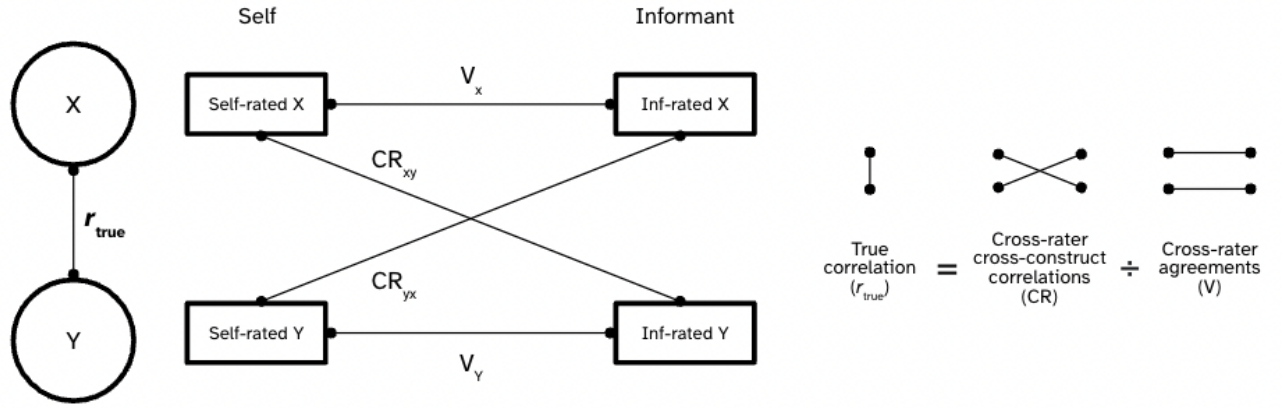
Participants' Big Five scores were calculated based on the 60 items derived by Anni et al. (2024). These were selected by (a) averaging standardized self- and informant-ratings; (b) dropping the item with less variance from each pair correlating above .50 and items with no correlation with any other item at least .30 (to avoid redundant as well as isolated items); (c) running principal component analysis (PCA) with the remaining 119 items, extracting five varimax-rotated components and retaining the 12 highest-loading items for each component; (d) re-running PCA with the remaining 60 items and using the resulting varimax-rotated loading matrix to generate participants' Big Five scores in self-reports and informant-reports (Table S1). This procedure ensured that Big Five scores were relatively orthogonal (median absolute inter-correlations Mdn = .05 and .04, respectively in self- and informant ratings); similarly calculated in self- and informant-reports; and

based on diverse yet internally consistent item content. Anni et al. (2024) provide extensive evidence for the reliability and construct, concurrent and criterion validity of these Big Five scores. In short, these Big Five scores correlated highly with those of multiple existing Big Five assessment scales, and also explain more variance in those scales than those scales explain in these scores.

EstBB personality study: first cohort. Personality traits were measured with the Estonian version of the NEO Personality Inventory–3 (NEO-PI-3; McCrae et al., 2005). The NEO-PI-3 items were responded to using a 5-point scale, and domains and facets were scored as sum scores of their items, as per the test manual. To determine whether our findings could be replicated using a more established measure, and across a ten-year time-span, we use this data containing the NEO-PI-3 to calculate the r_{true}s between the NEO-PI-3 personality dimensions and our loneliness measure.

Loneliness. We assessed loneliness with a single item, '*Often feel lonely*'. This item assesses loneliness in the most face-valid way possible and closely matches the UK National Health Service's definition of loneliness (Veazie et al., 2019, Appendix F). Also, using a narrowly and face-validly defined loneliness assessment helped us avoid conceptual issues around distinguishing other constructs from broadly defined loneliness. Direct single-item measures of loneliness have been supported by the literature (Thompson & Pollet, 2023) and are often the standard in large panel surveys (e.g. Surkalim et al., 2023). Because we used error-correction methods (described below) to address random and transient errors and stable single-method biases, the usual concerns about the reliability of single-item measures do not apply. We have already explored the validity of this single-item loneliness measure (1iL; Maher et al., 2025), finding it converges closely with established measures of emotional loneliness, with error-corrected correlations of .97 with the short-UCLA (Hughes et al., 2004) and .89 with the DJG Emotional loneliness subscale (Gierveld & Tilburg, 2010). Descriptive characteristics for all psychometric variables are reported in Supplementary Table S2.

Figure 1. Summary of r_{true}s and calculation



$$\frac{\sqrt{abs(CR_{xy} * CR_{yx})}}{\sqrt{V_x * V_y}} = r_{true}$$

Note. This formula produces the absolute value for r_{true} which must be corrected to match the sign of the arithmetic mean of the *CR*s. In rare cases where the *CR*s are opposite signs, their arithmetic mean is used as the numerator, rather than their geometric mean.

Table 1. The highest r_{true} estimates, compared to raw self-report correlations

Item pair		r_{true}			r_{self}		
		ET	**RU**	**EN**	**ET**	**RU**	**EN**
Keep my promises	Break my promises	–.97	-1.02	-1.02	-.65	-.66	-.61
Having good friends is important for me	Have no need for close friendships	-.97	-.84	-.91	-.69	-.62	-.68
Have strong sexual urges	Don't think much about sex	-.97	-.97	-1.00	-.79	-.71	-.74
Am always worried about something	Rarely worry	-.94	-.94	-.93	-.68	-.66	-.63
Act without thinking	Make rash decisions	.93	.84	.86	.67	.50	.57

Note. Adapted from Mõttus et al., (2024). Longer list presented in the supplementary materials (Table S3). r_{true} = true correlations, r_{self} = self-report correlation.

Analyses

All analyses were conducted using R Studio, version 4.1.2 (R Core Team, 2021) and were not pre-registered.

True Correlations. The key ideas and details, including a full algebraic representation, of using r_{true}s to accurately assess correlations between questionnaire-based constructs have been described elsewhere (Henry et al., 2024; Mõttus et al., 2024). In short, correlations are typically calculated based on single-method data (e.g., self-reports), but these are distorted by random error and occasion-specific effects (e.g., mood, recent events) as well as stable single source method (self-reporter) biases. Informant reports have been used to validate results from self-report data, but are themselves subject to biases and errors. However, cross-rater cross-construct correlations (*CR*; for instance, the correlation of informant-rated loneliness with self-rated Openness) are not affected by any shared sources of bias, thus only representing the underlying correlation between the two variables. However, *CR*s are diluted by factors that make raters disagree even for the ratings of the same constructs, such as random or transient error or biases not shared among the constructs (e.g., idiosyncratic item interpretations). Therefore, by taking the ratio of the averaged *CR*s and averaged cross-rater same-construct correlations (*V*s) we derive the r_{true}, an error-corrected estimate of the association between those constructs in our sample (Fig. 1).

Generally, the r_{true}s tend to be larger than self-report-based correlations and can approach 1.00 for semantically-identical items, supporting their validity (for examples, see Table 1). Importantly, calculating r_{true}s does not presume that both methods are exactly equally valid for assessing both constructs (Mõttus et al., 2024). As a corollary, we could also apply this methodology to identify the relationships of age and sex with loneliness. In these cases, these variables can be conceptualised as a psychometric variable with a perfect 'cross-rater agreement' of 1.0. The standard errors (*SE*) of r_{true}s were calculated according to Mõttus et al. (2024).

As another corollary, we used structural equation modelling to perform multivariate analyses of true correlations, modelling the true independent associations between the Big Five and loneliness from the shared variance between the self and informant assessments. Each latent construct was indicated by its respective self- and informant-rated scores, and Loneliness was simultaneously regressed on all Big Five domains. This approach is akin to our method of estimating associations from the shared variance between multiple raters. However, we note that structural equation models cannot be used to estimate bivariate associations because the required residual correlates between self-reports and between informant-reports to account for shared biases would entail negative degrees

of freedom; this is why the r_{true} approach is more flexible and was used for bivariate analyses. From these models, R^2_{true} values could also be extracted, representing the true predictive accuracy of the Big Five. Full details of these models, including allowed covariances, are reported in the Supplementary Materials.

Genetic correlations. Among familially related participants, Mõttus et al. (2025) combined self- and informant-ratings to estimate life satisfaction's genetic and environmental correlations with the Big Five domains. Here, we followed the same approach, substituting life satisfaction with loneliness. We fitted separate models for each Big Five domain (Fig. 2). First, we defined both loneliness and the personality trait being related to loneliness as latent traits of the shared variance of their self- and informant-ratings, separately for both relatives of a relative pair. Second, for both constructs, we defined latent variables representing additive genetic influences (A) and unique environmental influences (E), again separately for both relatives, while also allowing for paths from the personality trait's A and E factors to the loneliness' latent trait. We fitted these models using multi-group structural equation modelling with robust maximum likelihood estimation, with sibling pairs, parent-offspring pairs and second-degree relative pairs constituting separate groups; while relatives' E factors were uncorrelated for all relative types, A factor had a .50 correlation for sibling and parent-offspring pairs but a .25 correlation for second-degree relatives. All parameters were fixed equal for both relatives and across groups. Finally, all self-ratings could have residual correlations, as could all informant ratings, and these could vary between groups.

The personality trait's and loneliness's additive genetic correlations were calculated as

$$r_A = \frac{a_t * a_{t \to l}}{\sqrt{{a_t}^2 * ({a_{t \to l}}^2 + {a_l}^2)}},$$

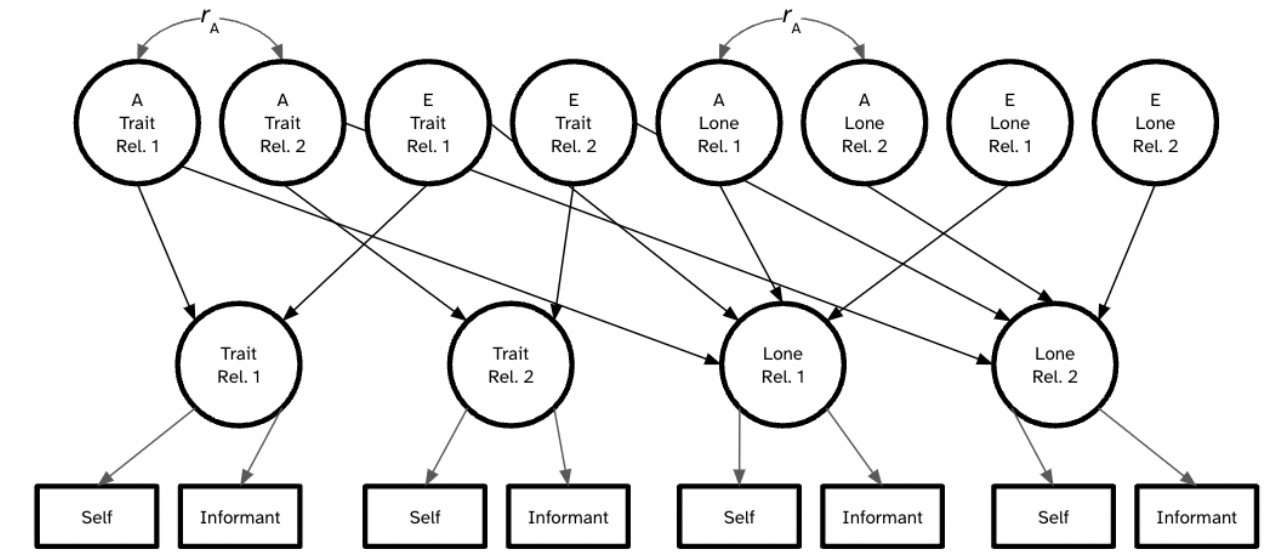
where a_t and a_l are the paths from the personality trait's and the loneliness' latent traits to their respective A factors, respectively, and $a_{t \to l}$ is the path from the personality trait's A factors to loneliness' latent factor. We applied the same calculations to environmental correlations, substituting the A-factor paths with E-factor paths.

The degrees to which additive genetic transmission contributed to the phenotypic trait-LS correlations, also known as bivariate heritability, were calculated as:

$${h_{tlone}}^2 = \frac{r_A * a_t * \sqrt{({a_{t \to lone}}^2 + {a_{lone}}^2)}}{r_p}$$

Here, r_p is the total phenotypic correlation between personality domain and loneliness. The same calculations were applied to the environmental influences' components. The numerators of these equations represented the genetic and environmental shares of the phenotypic correlations.

Figure 2. Path model for genetic correlation analyses



Note: r_A = genetic relatedness (either 0.5 or 0.25 in our sample); A = additive genetic factors; E = unique environmental factors.

Table 2. Single-rater correlations in ET/RU/EN samples

	Age	Sex*	Neuroticism	Agreeableness	Extraversion	Conscientiousness	Openness	Loneliness
Age	–	-.04 / .12 / -.07						-.03 / -.09 / -.14
Sex*	-.04 / .12 / -.07	–						.14 / .09 / .15
Neuroticism			–	.08 / .10 / .07	-.01 / .01 / -.11	-.04 / -.12 / -.05	.00 / -.02 / -.10	.51 / .45 / .45
Agreeableness			.08 / .03 / .04	–	-.01 / -.03 / -.05	-.06 / -.05 / .08	-.11 / -.06 / -.04	-.10 / -.11 / -.19
Extraversion			.05 / .04 / -.09	.03 / .13 / .01	–	.00 / .02 / .08	-.04 / .04 / .03	-.19 / -.18 / -.14
Conscientiousness			.06 / .01 / .07	-.04 / .01 / .17	-.08 / -.06 / .10	–	-.16 / -.05 / -.09	-.11 / -.15 / -.11
Openness			-.02 / -.02 / .00	.11 / .01 / -.01	-.06 / -.03 / .00	-.03 / .00 / .02	–	.00 / -.01 / .00
Loneliness	-.16 / -.23 / -.26	.04 / -.04 / .09	.47 / .39 / .45	-.10 / -.10 / -.17	-.15 / -.24 / -.12	-.09 / -.16 / -.08	.01 / .04 / -.01	–

Note. Informant-report intercorrelations are above the diagonal, and self-report intercorrelations are below the diagonal. The first number shows the result from the ET sample, the second number shows the result from the RU sample, and the third number shows the result from the EN sample. * ET and RU samples had information about their biological sex determined at birth, whereas the EN sample was asked about gender. M was coded as 0, F was coded as 1; seven EN subjects who did not report gender information were coded as 0.5.

Table 3. Cross-rater, cross-variable correlations in ET/RU/EN samples

	Age	Sex*	Neuroticism	Agreeableness	Extraversion	Conscientiousness	Openness	Loneliness
Age	–	-.04 / .12 / -.07						-.03 / -.09 / -.14
Sex*	-.04 / .12 / -.07	-						.14 / .09 / .15
Neuroticism			**.56 / .48 / .48**	.10 / .06 / .05	-.01 / .00 / -.07	.02 / -.01 / .02	-.02 / -.09 / -.05	.32 / .26 / .32
Agreeableness			.12 / .09 / .05	**.46 / .40 / .39**	.01 / .04 / -.05	-.03 / .01 / .01	-.04 / -.04 / .03	.02 / -.01 / -.12
Extraversion			.04 / -.03 / .03	-.02 / -.01 / .02	**.59 / .51 / .48**	-.04 / -.03 / .02	-.10 / -.08 / -.06	-.08 / -.14 / -.12
Conscientiousness			.01 / -.06 / -.02	-.12 / -.08 / -.02	-.04 / .03 / .02	**.52 / .50 / .45**	-.15 / -.08 / -.08	-.02 / -.08 / -.08
Openness			.01 / .01 / -.02	-.06 / -.05 / -.05	-.05 / -.02 / -.02	-.18 / -.13 / -.06	**.51 / .45 / .41**	.04 / .05 / .02
Loneliness	-.16 / -.23 / -.26	.04 / -.04 / .09	.28 / .26 / .30	-.02 / .01 / -.06	-.12 / -.17 / -.08	-.07 / -.06 / -.06	.03 / .02 / -.07	**.38 / .36 / .41**

Note. Rows represent self-rated traits, columns represent informant-rated traits, with the diagonal, in bold, representing the cross-rater agreement for each trait. The first number shows the result from the ET sample, the second number shows the result from the RU sample, and the third number shows the result from the EN sample. * ET and RU samples had information about their biological sex determined at birth, whereas the EN sample was asked about gender. M was coded as 0, F was coded as 1; seven EN subjects who did not report gender information were coded as 0.5.

Table 4. r_{true}s in ET/RU/EN samples

	Age	Sex*	Neuroticism	Agreeableness	Extraversion	Conscientiousness	Openness	Loneliness
Age	-	.006 / .029 / .033	.006 / .033 / .037	.007 / .036 / .041	.007 / .034 / .040	.007 / .034 / .039	.007 / .034 / .042	.007 / .036 / .038
Sex*	-.04 / .12 / -.07	-	.006 / .031 / .035	.006 / .036 / .041	.006 / .032 / .038	.006 / .034 / .039	.007 / .034 / .041	.007 / .038 / .040
Neuroticism	-.23 / -.24 / -.25	.42 / .40 / .37	-	.008 / .044 / .050	.008 / .043 / .048	.008 / .043 / .050	.008 / .044 / .050	.007 / .041 / .043
Agreeableness	.05 / .14 / .14	.22 / .19 / .20	.22 / .18 / .12	-	.008 / .045 / .051	.008 / .045 / .053	.008 / .045 / .053	.009 / .049 / .052
Extraversion	-.03 / .14 / -.08	.35 / .30 / .21	.06 / -.06 / -.01	-.02 / .02 / -.03	-	.008 / .042 / .050	.008 / .043 / .050	.008 / .042 / .048
Conscientiousness	.10 / .14 / .18	.17 / .13 / .20	.02 / -.06 / -.04	-.12 / -.17 / -.05	-.07 / .04 / .06	-	.007 / .041 / .050	.009 / .045 / .050
Openness	-.15 / -.21 / .07	-.14 / -.22 / -.09	.00 / -.07 / -.07	-.10 / -.10 / -.08	-.13 / -.08 / -.07	-.32 / -.21 / -.16	-	.009 / .047 / .052
Loneliness	-.11 / -.24 / -.30	.12 / .00 / .17	.65 / .62 / .69	.02 / .01 / -.19	-.21 / -.35 / -.23	-.08 / -.17 / -.18	.08 / .07 / -.14	-

Note. True correlations (r_{true}s) between all measures are shown below the diagonal. Standard errors are shown above the diagonal. The first number shows the result from the ET sample, the second number shows the result from the RU sample, and the third number shows the result from the EN sample. * ET and RU samples had information about their biological sex determined at birth, whereas the EN sample was asked about gender. M was coded as 0, F was coded as 1; seven EN subjects who did not report gender information were coded as 0.

Results

Cross-sectional associations between loneliness and the Big Five domains

Loneliness' single-method correlations with the Big Five are in Table 2 for the ET, RU, and EN samples. We also report correlations with age and sex as corollary findings in the same table. Similarly to previous studies, loneliness correlated most strongly with Neuroticism in both the self- and informant-data (r_{self} = .39 to .47 and $r_{informant}$ = .45 to .51, respectively). No other domain correlated with loneliness more strongly than r = .20 in any sample or rating type, except Extraversion in the RU self-report data (r_{self} = -.24).

Personality trait and loneliness cross-rater, cross-construct and cross-rater, same-construct correlations are reported in Table 3. Cross-rater, same-construct correlations were in the typical range for the Big Five domains (Connelly & Ones, 2010). Our loneliness assessment item, '*I often feel lonely*', had cross-rater agreements of .36 to .41, higher than typical for single items ($r \approx .30$; Henry & Mõttus, 2022). Loneliness' cross-rater correlations with the Big Five domains were lower than the single-method correlations, being r = .26 to .32 for Neuroticism and considerably lower for other domains. This was expected, given that raters do not agree perfectly. Generally, cross-rater, cross-construct correlations were similar in both directions (above and below the diagonal in Table 3), suggesting that self- and informant-rated loneliness have similar personality correlates and thereby supporting the validity of informant-reported loneliness.

Loneliness's r_{true}s with Neuroticism ranged from .62 to .70 (Table 4), notably higher than the single-rater correlations and higher than those in any previous large studies. Loneliness' r_{true}s with Extraversion ranged from r_{true} = -.21 to -.35, which is somewhat higher than single-method correlations, and its r_{true}s with Conscientiousness ranged from r_{true} = -.08 to -.18, comparable to our single-method findings. Loneliness's r_{true}s with Agreeableness (r_{true}s = .02, .01, and -.19 for EN, RU and EN samples, respectively) and Openness (r_{true}s = .08, .07, and -.14) were small and varied more across samples than single-method correlations. At the individual item level, in all samples, loneliness's highest correlation with any other item from the 100-NP was '*Often feel blue*' (ET/RU/EN r_{true} = .86/.83/.87; Table S3). This item was not included in the Big Five calculations, so it did not inflate the Big Five-loneliness correlations. Ironically, however, feeling lonely and blue are combined in a Neuroticism scale of a popular Neuroticism test ('*I rarely feel lonely or blue*'; Costa & McCrae, 1992).

We also ran multivariate analyses using structural equation modelling. There, the true association between agreeableness and loneliness were somewhat higher than in our r_{true} analyses,

with ß$_{true}$s of -0.14/-0.09/-0.29 respectively for ET/RU/EN samples. Results for other domains were broadly comparable to our r_{true}s. Model fits were good. We report the full methods and results for our multivariate analyses in the supplementary materials (Table S4). Finally, we extracted the R^2_{true} values for loneliness and the Big Five from these models, which were R^2_{true} = .52/.52/.62 for the EN/RU/EN samples, meaning that over half of the true variance in loneliness was predictable from the Big Five. The equivalent R^2 values were R^2 = .29/.26/.25 and .33/.27/.26 in self- and informant-report models. That is, the amount of variance that the Big Five explained in loneliness was nearly twice as high in multi-rater data compared to typical single rater data.

Longitudinal associations between loneliness and the Big Five domains

We calculated longitudinal r_{true}s similarly to cross-sectional r_{true}s, except that personality domains had been assessed with the NEO-PI-3 instead of the 100-NP, and about ten years before loneliness assessment. The longitudinal r_{true}s between the corresponding Big Five domains ranged from r_{true} = .70 to .82. Given that correlations of the Big Five domains over ten years assessed with the same questionnaire tend to be between r = .63 to .75 (Hopwood et al., 2013), we interpret these findings to indicate at least good convergence between the NEO-PI-R and 100-NP, as also suggested by the correlations of the 100-NP Big Five scores with other Big Five assessments (Anni et al., 2024). No inter-domain r_{true}s were above .30 in magnitude.

For loneliness, the longitudinal r_{true}s (Table 5) were similar to cross-sectional r_{true}s (Table 4), but slightly lower. Neuroticism correlated with loneliness ten years later r_{true}s = .53, while the correlations were respectively r_{true} = -.21 and .-14 for Extraversion and Agreeableness, and negligible for Openness and Conscientiousness. For reference, we provide single-method (self-reports) correlations which are lower for these three domains. Therefore, loneliness' associations with Neuroticism and Extraversion largely endured over time, hence being largely driven by either genetic or stable environmental influences rather than events that could happen within the approximately 10 years in between the two testing occasions. For agreeableness, our findings are less clear: due to differences between assessment tools or sampling error, the longitudinal correlation was even higher than the cross-sectional one; although it was equal to the estimate in our multivariate cross-sectional analyses (Table S4).

Genetic and environmental associations

Models decomposing the Big Five-loneliness associations into genetic and environmental components fit the data well (Table S7). The loneliness' heritability estimate was h^2 = 0.43, while those of the Big Five domains were h^2 = 0.44, 0.27, 0.28, 0.58, and 0.44 for Neuroticism, Agreeableness, Extraversion, Conscientiousness and Openness, respectively, as reported in Mõttus et al. (2025). Hence, loneliness was as heritable as the Big Five. Loneliness had genetic and environmental correlations of r_A/r_E = .71/.62 with Neuroticism, -.14/-.06 with Agreeableness, -.02/-.40 with Extraversion, -.26/.07 with Conscientiousness, and .14/-.26 with Openness (Table 6). Only the genetic correlation estimate for Neuroticism and loneliness was significant (Table S5). Given the heritability estimates and genetic and environmental correlations, the genetic contributions to the links between loneliness and personality domains were overall similar to the environmental contributions, but varied across domains. For example, Neuroticism's correlation with loneliness was almost equally driven by genetic and environmental factors, amounting to a bivariate heritability of $h_{bivariate}^2$ = .47. Full model outputs, as well as the model path diagrams, are reported in the supplementary materials (Tables S5–7; Figs. S1–5).

Table 5. Ten-year longitudinal correlations between personality and loneliness

	Later Big Five				Later Loneliness			
Earlier Big Five	r_{self}	SE_{self}	r_{true}	SE_{true}	r_{self}	SE_{self}	r_{true}	SE_{true}
Neuroticism	.66	0.024	.73	0.039	.44	0.034	.53	0.047
Agreeableness	.58	0.043	.82	0.047	-.09*	0.043	-.14**	0.056
Extraversion	.61	0.040	.70	0.035	-.16	0.042	-.21	0.049
Conscientiousness	.59	0.043	.72	0.042	-.09*	0.043	*-.05*†	0.055
Openness	.50	0.043	.72	0.023	*-.00*†	0.043	*-.02*†	0.053

Note. All estimates significant to $p < .001$ unless stated otherwise: † $p > .05$; * $p < .05$; ** $p < .01$. r_{true} = true correlation. We provide single-method correlations (r_{self}) for reference.

Table 6. The genetic and environmental associations between personality traits and loneliness

Domain	h^2	r_A	r_E	Genetic share	Environmental share	r_p	$h_{bivariate}^2$
Neuroticism	.44	.71	.62	.31	.35	.66	.47
Agreeableness	.27	-.14†	-.06†	-.05	-.04	-.08	.56
Extraversion	.28	-.02†	-.40**	-.01	-.26	-.26	.03
Conscientiousness	.58	-.26†	.07†	-.13	.03	-.10	.79‡
Openness	.44	-.14†	.26†	.06	.15	.09	.29‡
Loneliness	.43						

Note. h^2 = narrow-sense heritability; r_A = additive genetic correlation; r_E = unique environmental correlation; genetic share of the phenotypic correlation is the product of the square root of loneliness' heritability estimate, the square root of the personality domain's heritability estimate, and their genetic correlation; environmental share of the phenotypic correlation is the product of the square root of loneliness' environmental estimate, the square root of the personality domain's environmental estimate, and their environmental correlation; r_p = total model-implied phenotypic correlation which is similar to r_{true} values in Table 4, but is restricted to the participant subsample with siblings; $h_{bivariate}^2$ = bivariate heritability, which is the proportion of the phenotypic true trait–loneliness correlation attributable to genetic influences. All h^2, r_A, and r_E estimates significant to $p < .001$ unless stated otherwise: † $p > .05$; * $p < .05$; ** $p < .01$; ‡ Genetic and environmental influences in opposite directions; figure represents genetic proportion of summed absolute effects.

Discussion

Using multiple samples and accounting for assessment errors and biases that have not been addressed so far, we found that loneliness was much more strongly tied to the Big Five personality traits than has been previously shown (Buecker et al., 2020). Collectively, the Big Five accounted for over half of the variance in loneliness. Individually, Neuroticism was by far the strongest loneliness' correlate, with $r_{true} \approx .60$ to .70. While other personality traits, or external-to-personality factors, are relevant to how often people experience loneliness according to themselves and people close to them, these factors must therefore be comparatively less important than Neuroticism. For example, even with the medium-sized association of $r_{true} \approx -.20$ to -.30, loneliness and Extraversion can easily coexist: people with high Extraversion are more likely to be in the medium/high range of loneliness than they are to be in the low range (Mõttus, 2022). Moreover, these links to Neuroticism and Extraversion were not only cross-sectional but endured over many years with nearly similar magnitudes. What is even more, Neuroticism had a strong genetic correlation with loneliness, with about half of its phenotypic correlations accounted for by genetic factors. So, whatever factors are linking Extraversion and, in particular, Neuroticism to loneliness (shared causality; mutual causality), they appear to be stable even over long periods of time and, in the case of Neuroticism, have sizeable familial roots. Loneliness was relatively weakly related to low Conscientiousness, whereas its links with Openness were inconsistent. While Loneliness had univariate correlations with Agreeableness of almost zero in the EN or RU samples, in our multivariate analyses we found respective $ß_{true}$s of -.14 ($p < .001$) and -.08 ($p = .192$). Estimates for Agreeableness were stronger in the smallest EN sample, $r_{true} = -.20$, $ß_{true} = -.29$ ($p < .001$), than in the by-far-largest Estonian- and also-smaller Russian-speaking samples.

We also found that by using multi-rater data, we were able to nearly double the Big Five's predictive accuracy of loneliness. Where single-rater R^2 values for loneliness and the Big Five were generally below $R^2 \approx .30$, using multi-rater methods, the Big Five we were able to explain over half of the variance in loneliness, $R^2_{true} \approx .50$ to .60 from the Big Five, approximately doubling the predictive accuracy.

Loneliness assessment

Our results differ from those of the largest to-date meta-analysis, which found similar associations of Neuroticism and Extraversion ($r = .36$ and -.37) with loneliness (Buecker et al., 2020). To a large extent, this is likely because of our use of multi-informant data that allowed us to calculate r_{true}s; in our self-rater analyses, the associations between loneliness and Neuroticism were closer to the usual range of effect sizes. Hence, it is only when we incorporate multi-rater data and are therefore able to accurately estimate loneliness' correlations with other traits that its correlations with

Neuroticism increase to the .60 to .70 range (Table 4). The typical findings have very likely underestimated the degree to which feeling lonely reflects the broad personality domain of Neuroticism. Some (e.g. Deason et al., 2025) have suggested that loneliness should be part of the assessment of Neuroticism. While we suggest further evidence is required to distinguish between strong causal associations and one being a genuine component of the other, psychometrically speaking, loneliness (when assessed by a direct measure) might indeed be a useful cross-sectional marker of Neuroticism, as determined by Costa & McCrae (1992).

More broadly, there are further discrepancies between our results and past findings. Our results are not only different in magnitude from those found previously, but they are also partly different in pattern. For example, while we found stronger associations for Neuroticism in our self-ratings analyses, we found r = -.12 to -.24 for Extraversion, lower than the aggregated r = .37 of Buecker et al. (2020). The reason for this may be the design of the loneliness assessment. The most widely-used loneliness scales, the R-UCLA (Russell et al., 1980) and the De Jong Gierveld (Gierveld & Tilburg, 2010), both avoid any mention of the word 'loneliness', and are also multi-dimensional, explicitly capturing variance related to outgoingness and having many friends, which are related but separable from loneliness (Coyle & Dugan, 2012; Maher et al., 2025; Maher & Cooper, 2025) but are constituent parts of Extraversion (e.g., Costa & McCrae, 1992). This directly Extraversion-related variance captured in these constructs may have led to the difference between their results, and ours; in other words, there may be some *a priori* construct overlap between Extraversion and the loneliness scales used in many past studies. Our direct and face-valid loneliness measure is inherently more uni-dimensional, which, in large samples and, in conjunction with r_{true}s (Mõttus et al., 2024), ensured that minimal off-target variance was represented in the final results. That is, we captured the common variance of the Big Five with frequent feelings of loneliness and less with being actively socially engaged.

Increased clarity of terms may help, and we have suggested the term 'loneliness' apply specifically to measures of emotions and feelings of loneliness, such as the 1iL or the 3-item UCLA-ES (Hughes et al., 2004; Maher et al., 2025). To describe the most popular multi-dimensional 'loneliness' scales like the R-UCLA and combined De Jong Gierveld (Gierveld & Tilburg, 2010; Russell et al., 1980), we suggest the term 'broad-sense loneliness' or similar be used (Maher et al., 2025). For 'social loneliness', capturing the state of not feeling close to others as in e.g. the subscale of the De Jong Gierveld (Gierveld & Tilburg, 2010), the term 'social disconnection' may be clearer (Eisenberger, 2012).

We also found that loneliness can be validly assessed by informants. Some may argue that while informant ratings may be valid when measuring more visible personality traits such as Extraversion, only self-ratings are valid when considering internal states, like feelings of loneliness. However, the correlations between self-rated personality and informant-rated loneliness are consistently similar to their reciprocals (between informant-rated personality and self-rated loneliness; Table 3). This strong symmetry suggests similar nomological networks. Also, loneliness had even stronger cross-rater correlations than is typical for personality items, suggesting that informant reports of loneliness contain no less consensually valid variance than informant reports of personality: a topic which has been well-covered and is well-supported (Olino & Klein, 2015). While informants cannot describe a partner's feelings first hand, these may be offset by the advantages of an outside perspective: it may for instance be easier to assess your partner's loneliness in the context of average levels than your own (Allik, 2019). We encourage researchers to adopt multi-rater methodologies across all areas of psychological assessment, even for traits that may, at first glance, be perceived as too internal or emotional to be assessable by an outsider.

Loneliness and other constructs

Our loneliness item's ('*Often feel lonely*') highest correlation with any other item was '*Often feel blue,*' an item originally from the Depression facet of Neuroticism (Johnson, 2014). For context, their r_{true} of .86 was comparable to those of '*Act as a leader*' with '*Want to be in charge*' (r_{true} = .85) or of '*Love order and regularity*' with '*Keep things tidy*' (r_{true} = .88).

Substantively, the very tight relationship to more general feelings of being down or 'blue' may have several implications. For example, loneliness may be barely related at all to the objective social environment, instead reflecting trait depression or things that cause trait depression. Alternatively, feelings of loneliness may have an impact on how we feel more generally, such as a poor social environment causing 'blue' mood as well as loneliness. Given that '*Often feel lonely*' does correlate strongly (r_{true} = -.65) with the more objectivity-oriented Oslo Social Support Scale (Example item: '*How many people are so close to you that you can count on them if you have great personal problems?*'; Kocalevent et al., 2018), the second hypothesis may be the better fit: that feelings of loneliness lie downstream of our social environments, and can result in feelings of 'blueness'.

Only a few studies have specifically explored the directionality of the link between depression and loneliness, and conclusions appear to vary with study interval length. Studies looking at intervals of hours (Kuczynski et al., 2024), and months (Wu et al., 2022) found that loneliness generally appears to precede depression, while annual studies have found a bi-directional link (Danneel et al.,

2019; Kristensen et al., 2023). Few studies have robustly investigated the direction of the depression-loneliness associations at time spans of more than a year, but one 14-year study looking at a large (*N* = 3,920) Taiwanese cohort of older adults with time point intervals of 3.5 years found notably stronger effects in the 'depression → loneliness' direction than the reverse (Hsueh et al., 2019).

Stability and origins of the associations

We found that Neuroticism, Extraversion, and Agreeableness all significantly predict future levels of loneliness, at a time span of 10 years. Previous research had found that only Neuroticism predicted future (15-year) loneliness with ß = .27 (Mund & Neyer, 2016). However, this study used only self-rated data and used the whole De Jong Gierveld scale (Gierveld & Tilburg, 2010) without separating its subscales that each capture lonely feelings and social disconnection (Maher et al., 2025).

By using multi-rater data about personality traits and loneliness from genetically related (25% or 50% shared DNA) individuals, we found that the durability of the Neuroticism–loneliness link can in part be explained by genetic overlap. That is, genetic factors that contribute to e.g. Neuroticism could also contribute to loneliness, an effect which will remain present across the lifespan, sustaining phenotypic correlations across even long time spans. While confidence intervals were relatively wide for models (Table S5), we closely replicated the previous finding showing that Neuroticism and Loneliness have strong genetic correlations (Abdellaoui et al., 2019). Hence, loneliness and Neuroticism tend to endure together, and also share many of their familial roots.

Limitations and Future Directions

While this study was able to obtain noise- and bias-free estimates of the relationship between loneliness and personality, reliance on informant-report data also means that people who have zero close ties in their life and might therefore represent the most socially disconnected people in society can be assumed to be under-represented in this sample. If this were the case, we may be failing to capture variance and therefore underestimating the true associations across the groups our samples represent. Although our familial relatedness subsample involved over 2,000 participants plus their informants and was therefore large by usual standards, robustly decomposing true associations into genetic and environmental components requires even larger samples. As such the confidence intervals around our genetic findings were relatively wide. Finally, while we used samples speaking three distinct languages, participants were overall almost exclusively European, and therefore caution is advised when making generalisations from our findings to non-European cultures; the age was also positively skewed in our English-speaking sample, with a majority of the participants 25 or younger.

The next steps are to infer the direction of any effect between these two: is loneliness a direct product of Neuroticism? Or are aspects of Neuroticism the result of a lifelong lack of social connection? Random-intercept cross-lagged panel studies (Mulder & Hamaker, 2021), using a direct measure of loneliness and incorporating multi-rater data, may be an appropriate method in future research to untangle the direction of this effect. Studies should also include measures of social disconnection alongside measures of lonely feelings, to determine any divergence in their effects and consequences, such as on mental health.

Earlier we defined loneliness as 'the feeling of being alone or isolated' (Veazie et al., 2019, Appendix F); another popular definition of loneliness is a 'perceived discrepancy between your current and desired relationships' (Peplau & Perlman, 1982). These definitions place a heavy emphasis on loneliness as a response to the social environment. However, this conceptualisation is only reconcilable with our findings (e.g. the $r_{true} \sim .90$ association we find between often feeling lonely and often feeling blue) through the explanation that aloneness and/or relationship quality are much more strongly linked to mood than previously understood. We encourage researchers to examine these links more closely, using direct measures and measurement error correction methods.

Going forward, researchers should also work to more clearly distinguish disconnection, loneliness and social isolation, which will require active investigation. Caution is needed when interpreting findings relating to these constructs, and these scales should be thoughtfully categorised when carrying out meta-analyses. We find that loneliness is relatively strongly related to Neuroticism, which has not proven an easy target for intervention (Sauer-Zavala et al., 2017). If the long-term goal is to improve mental health outcomes, social disconnection may be worth exploring more deeply, as it is of known importance to mental well being (Wang et al., 2018), and might be more actionable than feelings of loneliness. It is also an area with a documented recent decline: in the US, the number of people reporting ten or more close friendships halved between 1990 and 2021, while the number of people reporting three or fewer close friendships appears to have nearly doubled (Cox, 2021), a change that, if found to be replicable and ongoing, merits deeper investigation.

Conclusions

The origin of loneliness is an important problem. Loneliness has been associated with many types of physical and mental health outcomes; however, we still do not know exactly where it comes from, or how it develops over the lifespan. Our study is to date the largest study to examine loneliness's associations with personality traits. Using multi-rater data, we were able to approximately double the amount of valid loneliness variance explained by the Big Five traits, in comparison to standard single-rater studies. In particular, Neuroticism correlated with loneliness much more strongly (r_{true} = .60 to .70) than has been shown in typical single-method studies (r < .40). Moreover, the key findings replicated well across samples; longitudinal data showed the main associations to endure over many years and the analyses of relative pairs showed that about half of loneliness' correlation with Neuroticism was for genetic reasons. Overall, we found multi-rater data and r_{true}s to be highly useful, allowing us to use even single-item measures to answer research questions without the usual — and typically unaddressed — assessment errors and biases. But even more importantly, because they circumvent both systematic single-method biases and random and transient errors, r_{true}s are robust to careless responding, idiosyncratic item interpretations, mood, acquiescence, demand characteristics and social desirability. The extra cost of collecting data with two methods is outweighed by the ability to collect data of equal validity with fewer items and therefore shorter surveys. If psychologists really care about accurately documenting their correlations, they should move beyond the currently-typical single-method designs.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest for this research.

ETHICS STATEMENT

No new data was collected and therefore ethical approval for this study was not sought. The activities of the EstBB are regulated by the Human Genes Research Act, which was adopted in 2000 specifically for the operations of the EstBB. Individual level data analysis in the EstBB was carried out under ethical approval 1.1-12/626, 13.04.2020 granted by the Estonian Committee on Bioethics and Human Research (Estonian Ministry of Social Affairs), using data according to release application 3-10/GI/11571 from the Estonian Biobank.

AUTHOR CONTRIBUTIONS

PM conducted all data analyses, and prepared all drafts of the manuscript. YD provided support on writing and assisted with early analyses and draft revisions. AC and UV reviewed successive manuscript drafts and contributed constructive feedback. RM was the principal investigator, directing the overall narrative, guiding analytical decisions, and providing extensive feedback on all manuscript drafts. The Estonian Biobank research team (Andres Metspalu, Lili Milani, Tõnu Esko, Reedik Mägi, Mari Nelis, and Georgi Hudjashov) was responsible for the initial data collection, genotyping, quality control, and imputed genotype dataset generation at the biobank. JA and AR initiated and oversaw the data collection for the first cohort of the EstBB personality study. All authors contributed to data interpretation, critically reviewed the manuscript, and approved the final version.

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